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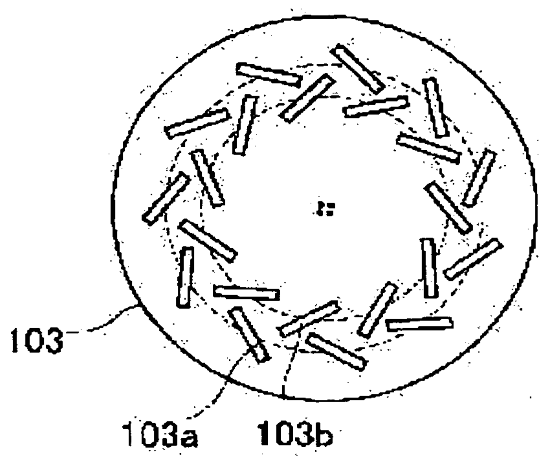
(54) MICROWAVE PLASMA TREATMENT DEVICE AND TREATMENT METHOD

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a microwave plasma treatment device and treatment method in which plasma treatment can be carried out with high reliability and stability using an antenna means which is strong mechanically or against thermal deformation even when high power microwave is radiated.
SOLUTION: The microwave plasma treatment device comprises an antenna means having slots provided on the microwave introduction face side of a dielectric window for transmitting a microwave. The antenna means is not inserted with a dielectric plate for shortening the wavelength in the tube and an atmospheric condition is present internally. A plurality of pairs of slots having different directions are arranged circularly only one round on a microwave radiation plate having a thickness of 0.5 mm-3.0 mm.



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CLAIMS

[Claim(s)]
[Claim 1] The exhaust air means for decompressing the inside of a microwave plasma treatment container, and the gas supply means for supplying the gas for exciting the plasma in this processing container, An antenna means to have the microwave radiation plate with which it is the antenna means formed in the microwave installation side side of the dielectric window for microwave transparency prepared in the wall surface of this processing container, and this dielectric window, and the slot was formed, In the microwave plasma treatment equipment constituted so that it may have the microwave generating means formed in the upstream of this antenna means, this dielectric window may be countered and a substrate may be installed in this processing container The interior of this antenna means does not have the dielectric plate inserted in order to shorten wavelength in tubing, and it is in an atmospheric condition. To the microwave radiation plate of this antenna means Microwave plasma treatment equipment with which the pair of the slot from which the sense differs mutually is characterized by arranging only two or more sets of round circularly.
[Claim 2] The microwave radiation plate of said antenna means is microwave plasma treatment equipment according to claim 1 characterized by thickness being 0.5mm or more and 3.0mm or less.
[Claim 3] The die length of said slot is microwave plasma treatment equipment according to claim 1 or 2 which sets about 1/to 2 and is characterized by the width of face being [of the guide wave length] 2mm or more and 8mm or less.
[Claim 4] Said dielectric window is microwave plasma treatment equipment according to claim 1 to 3 characterized by having the ring-like sleeve so that a plasma excitation field may not contact the surface of metal of a direct-processing vessel wall at the periphery section of the field by the side of said processing container.
[Claim 5] Said dielectric window is microwave plasma treatment equipment according to claim 1 to 4 characterized by being what constituted so that it may have the thickness in which the shape of surface type and thickness of the center section were adjusted in the field, and the field of the dielectric window corresponding to the predetermined field of said substrate differed from other fields.
[Claim 6] Said dielectric window is set to one field of the field by the side of the processing container, and the fields by the side of microwave installation. [whether it is constituted so that heights may be prepared in the field of the dielectric window corresponding to the predetermined field of said substrate and the thickness of the field of the dielectric window corresponding to the predetermined field of this substrate may become thicker than the thickness of other fields, and] Or a crevice is established also in this field corresponding to heights of a field and the field of an opposite hand in which these heights were prepared. Microwave plasma treatment equipment according to claim 1 to 4 characterized by being constituted so that the thickness of the prepared field of these heights and a crevice may become the same as the thickness of other fields.
[Claim 7] Said dielectric window is microwave plasma treatment equipment according to claim 1 to 4 characterized by being constituted so that a concentric circular level difference may be

prepared in the field by the side of the processing container, it may be made for the distance from said substrate front face to the front face of this dielectric window to change with fields of a substrate and the consistency of the plasma to generate may become homogeneity on this substrate.
[Claim 8] Microwave plasma treatment equipment according to claim 7 characterized by preparing discontinuously the concentric circular level difference of said dielectric window in the direction of a path of this dielectric window for the diameter of 1/2 wave of integral multiple.
[Claim 9] Said dielectric window is microwave plasma treatment equipment according to claim 1 to 8 which has the center-section field which has different thickness from other fields, the field which has heights, and the field which has a concentric circular level difference, and is characterized by the thickness of these fields being about [of the wavelength of the microwave in a dielectric] 1/4.
[Claim 10] The material gas for exciting the plasma with a gas supply means is supplied in a microwave plasma treatment container. Exhaust a raw material and reaction secondary generation gas with an exhaust air pump, and the inside of a container is made reduced pressure. Introduce into an antenna means to have the microwave radiation plate with which the slot was formed in the microwave made to oscillate and amplify with a microwave generating means, and it emanates through a slot. The emitted microwave is introduced through a microwave transparency aperture into this processing container under a reduced pressure installation gas ambient atmosphere. The electromagnetic field which this microwave makes generate the plasma in a processing container. The microwave plasma treatment approach which is the plasma treatment approach which consists of carrying out microwave plasma treatment of the substrate which countered this dielectric window and was formed, and is characterized by performing plasma treatment using microwave plasma treatment equipment according to claim 1 to 9.
[Claim 11] The frequency of the microwave which the pressure of the gas in said processing container is 0.1Pa - 1000Pa, and is impressed to an electrode is the microwave plasma treatment approach according to claim 10 characterized by being 2GHz - 10GHz.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the plasma treatment approach of using microwave excitation plasma treatment equipment (microwave plasma treatment equipment being called hereafter.) and this equipment. It is plasma equipment which has a microwave radiation antenna for introducing microwave until 0.5W /results in the large power flux density of 2 to 20 W/cm2 cm especially. It is involved in the equipment for plasma processes which can perform improvement and refining of membrane formation, etching, and a film presentation, and ashing at the substrate which is a processed material in semi-conductor LSI production, and the plasma treatment approach using this equipment.
[0002]
[Description of the Prior Art] In recent years, as for micro processing of a wafer, sheet processing is in use with diameter[of macrostomia]-izing of detailed-izing of the device in Semi-conductor LSI, and a wafer. In the plasma process of CVD in it, or etching, the source of the plasma of DC or high-frequency excitation is used. Moreover, ECR (electron cyclotron resonance) is used in the source of the plasma using microwave. In the case of the plasma excited by the RF or ECR as mentioned above, it was difficult to generate the uniform plasma with the diameter of macrostomia the top to be impressed [of a magnetic field] in order to generate the plasma of high density. Moreover, there were also a problem that carry out sputtering of the chamber wall and metal contamination occurs since plasma potential is as high as about 20eV, and ion irradiation energy [further as opposed to a floating substrate] and the problem of giving a damage to a substrate with 10eV or more since it is high.
[0003] Then, the method with which electron temperature generates the surface wave plasma of low high density also with low plasma potential is developed by introducing microwave into a vacuum ambient atmosphere through a dielectric from a slot, and making strong microwave electric field using antenna means, such as a radial line slot antenna (following: calling RLSA.). For example, with the equipment of a patent [No. 3136054] publication, the dielectric is inserted in the interior of an antenna and it is supposed that the plasma can be generated by emitting circularly-polarized-wave microwave for a slot from a concentric circle or the pattern arranged spirally under a certain regulation, without using a magnetic field efficiently. [many]
[0004] On the other hand, the dielectric window of microwave permeability is not installed in a chamber wall by patent No. 2928577, but the equipment which performs a vacuum seal with the dielectric inside an antenna and the waveguide of an antenna is indicated. "Two or more slits of the shape of a thin line from which the sense differs mutually are arrays in large numbers to the shape of a concentric circle or a swirl" of the slot is carried out, and it shortens guide wave length lambdag inside an antenna with the dielectric inside an antenna. Moreover, by using a magnetic field, it supposes that the plasma is generated by the synergistic effect of microwave and a magnetic field, and working pressure is dramatically made into low voltage with the 10-3Torr base (- 10-1Pa base).
[0005]
[Problem(s) to be Solved by the Invention] However, when the antenna of the above-mentioned

conventional technique aiming at inserting a dielectric in the interior of an antenna, shortening guide wave length lambdag, and forming as many slots as possible in a microwave radiation plate, and performing homogeneity and efficient microwave radiation in a field is used, a microwave radiation plate deforms with time with generation of heat and the heat from a substrate side, and there is a problem that the plasma becomes instability. Moreover, when the microwave radiation plate deformed and the clearance was made between the microwave radiation plate and the dielectric inside an antenna, abnormality discharge started by electric-field concentration etc., and there was also a problem of occasionally damaging a dielectric.

[0006] This is because thickness of a microwave radiation plate had to be made very thin with about 0.3mm and heat conduction of the part, a mechanical strength, or the direction of a path got very bad, in order to write guide wave length lambdag short by putting a dielectric into the interior of an antenna and to be made not to worsen a radiation property. Although the antenna which formed the direct thin film in the metallic conductor which the slot for functioning as an antenna opened by technique, such as vacuum evaporationo and plating, was proposed to these problems using dielectrics, such as a ceramic, there was a problem that the film separated according to the difference of the expansion coefficient between the ingredients by heat, and the technical problem was in adhesion. Furthermore, it was what it is hard to use general-purpose also in respect of a manufacturing cost or a delivery date.

[0007] Moreover, there is a problem that equipment will complicate a microwave radiation plate according to problems, such as heat removal, although adhesion or the device which carries out a pressure welding and suppresses deformation is also considered by the dielectric inside an antenna and the microwave transparency aperture by the side of a vacuum housing. To the problem why guide wave length lambdag must use a thin microwave radiation plate (namely, slot of thin thickness) when short as described above, he can understand by calculating the trespass length to a slot and transparency power of microwave. This point is explained below.

[0008] First, the power P which penetrates a slot can be expressed with a degree type (1).

(Formula 1)

P = P0 exp (-t2/delta) .... (1)

Here, they are P0:charge power, the thickness of t:slot, and delta:trespass length. The power P which can penetrate a slot decreases exponentially in proportion to the square of slot thickness so that clearly from a formula (1). Moreover, the trespass length delta is given by the degree type (2).

(Formula 2)

$$\delta = 1/(2\pi\sqrt{(1/2a)^2 - (1/\lambda g)^2}) \quad \cdots\cdots (2)$$

Here, they are the die length of the long side of a:slot, and the guide wave length of lambdag:microwave.

[0009] Moreover, when die-length a of the long side of a slot is or more lambdag/2 in this formula (2), the sign in the root becomes zero or minus. When the die length of a slot long side is longer than the one half of the guide wave length, this means that microwave can transmit power like a waveguide, however thick the thickness of the slot over the travelling direction of microwave may be. However, in order to control to usually take out power with a flat surface, many less than 1/2 slots of the guide wave length are cut with the antenna which emits microwave at a flat surface like this time by the upstream of the propagation of microwave. In addition, since all power may be made to be emitted to the slot by the side of the lowest style cut by the concentric circle, it is not this limitation.

[0010] From the above formula (1) and (2), when it is a time of guide wave length lambdag being 100mm, and 40mm, it asks for the trespass length when setting die-length a of the long side of a slot to a=(lambdag / 2-0.5) mm, respectively actually, for example. In addition, when an alumina was used as a dielectric, since lambdag was set to about 1/rootepsilon to the wavelength (122mm @ 2.45GHz) of free space, it calculated as lambdag=40mm as follows from becoming about lambdag=40mm actually. - At the time of lambdag=100mm, it is a= 49.5 and is set to delta= 111.8mm. - At the time of lambdag=40mm, it is a= 19.5 and is set to delta= 27.9mm.

[0011] These values are assigned to a formula (1) and the difference in the power transmittivity

when changing slot thickness t, respectively is summarized in a table 1. (A table 1)

管内波長	アンテナ	電力透過率 (%)			
λg (mm)	内部の材料	t=0.3	t=0.5	t=1.0	t=3.0
100	なし	99.5	99.1	98.2	94.8
40	アルミナ	97.9	96.5	93.1	80.7

[0012] In case microwave penetrates a slot so that guide wave length lambdag is short in spite of carrying out near of the die length of the long side of a slot to lambdag/2 so that the result of a table 1 may also show (when a dielectric is used), it is greatly influenced of the thickness, and transparency power will decrease extremely, so that slot thickness is thick. Moreover, if the value of die-length a of this slot long side becomes still shorter and trespass length also becomes short, it will come to be further influenced of thickness. In addition, since it does not fill up with the dielectric in the thickness direction of a slot strictly when a dielectric is in the interior of an antenna, wavelength will become long extremely immediately after emitting microwave from a slot, and the effect of thickness is actually predicted to come out further.
[0013] In the conventional technique, the above is [guide wave length lambdag] a reason for having to use a thin slot plate, when short. Even if the technical problem of this invention is to solve the problem of the above-mentioned conventional technique and performs microwave radiation of large power from an antenna means, it is by using an antenna means strong also against thermal deformation and a thermal mechanical strength to offer the microwave plasma treatment equipment which can perform reliable and extremely stable plasma treatment, and the art using this equipment.
[0014]
[Means for Solving the Problem] The microwave excitation plasma treatment equipment of this invention The exhaust air means for decompressing the inside of a microwave plasma treatment container, and the gas supply means for supplying the gas for exciting the plasma in this processing container, An antenna means to have the microwave radiation plate with which it is the antenna means formed in the microwave installation side side of the dielectric window for microwave transparency prepared in the wall surface of this processing container, and this dielectric window, and the slot was formed, In the microwave plasma treatment equipment constituted so that it may have the microwave generating means formed in the upstream of this antenna means, this dielectric window may be countered and a substrate may be installed in this processing container The interior of this antenna means does not have the dielectric plate inserted in order to shorten wavelength in tubing, and it is in an atmospheric condition, and the pair of the slot from which the sense differs mutually becomes the microwave radiation plate of this antenna means from only two or more sets of round being arranged circularly. More than one are arranged circularly, the pair of such a slot adjoining mutually.
[0015] The microwave radiation plate of this antenna means has the thickness of 0.5mm or more and 3.0mm or less. It is easy to deform thermally with being less than 0.5mm, and a mechanical strength is also low. Moreover, if it exceeds 3.0mm, the radiation property of microwave will worsen. In the microwave plasma treatment equipment of this invention, in order to remove heat efficiently from a microwave radiation plate, it is desirable that a channel is cut on the inner shaft and the body of an antenna of a coaxial tube, and it can be made to carry out to them water cooling and to set board thickness of the microwave radiation plate to about 1.0mm further. Although the distortion by heat stops being able to happen easily since clearance of heat is promoted so that thickness becomes thick, and also reinforcement of a microwave radiation plate increases, the radiation property of microwave will worsen. The optimal thickness is set to about 1.0mm to these both problem. Of course, this optimal thickness changes with guide wave lengths in the charge power (power flux density) of microwave, or an antenna.
[0016] Moreover, generally about [of the guide wave length in an antenna] 1/2 and its width of face of the die length of the slot which was able to be opened in the microwave radiation plate are from 4mm to about 8mm preferably from 2mm to about 8mm. It is because there is a possibility of disturbing the electromagnetic field of the microwave which the effect of crosswise

electric field emits when there is a problem that intensity of radiation falls that it is less than 2mm since opening is small and it exceeds 8mm. When tested using the microwave radiation plate which has the slot of 2mm, 4mm, and 6mm width of face, a result by which the thing of 6mm width of face is stabilized most among those was brought.

[0017] According to this invention, as for the dielectric window for microwave transparency, it is desirable to have the ring-like sleeve so that a plasma excitation field may not contact the surface of metal of a direct-processing vessel wall at the periphery section of the field by the side of a processing container. Moreover, the shape of surface type and thickness of the center section may be adjusted in a field, and the dielectric window for microwave transparency may be constituted so that it may have the thickness in which the field of the dielectric window corresponding to the predetermined field of a substrate differed from other fields. A dielectric window is set again to one field of the field by the side of the processing container, and the fields by the side of microwave installation. [whether it is constituted so that heights may be prepared in the field of the dielectric window corresponding to the predetermined field of a substrate and the thickness of the field of the dielectric window corresponding to the predetermined field of a substrate may become thicker than the thickness of other fields, and] Or a crevice is established also in the field corresponding to heights of a field and the field of an opposite hand in which these heights were prepared, and it may be constituted so that the thickness of the prepared field of these heights and a crevice may become the same as the thickness of other fields.

[0018] Furthermore, a dielectric window prepares a concentric circular level difference in the field by the side of the processing container, it is made for the distance from a substrate front face to the front face of a dielectric window to change with fields of a substrate, and it may be constituted so that the consistency of the plasma to generate may become homogeneity on this substrate. This concentric circular level difference may be discontinuously prepared in the direction of a path of a dielectric window for the diameter of 1/2 wave of integral multiple. Moreover, a dielectric window may have the center-section field which has different thickness from other fields, the field which has heights, and the field which has a concentric circular level difference, and the thickness of these fields may be about [of the wavelength of the microwave in a dielectric] 1/4.

[0019] After considering that the thermal reinforcement and the mechanical strength of a microwave radiation plate described above according to this invention While using 0.5-3.0mm, and 1 desirablemm and a desirable thick thing compared with 0.3 conventionalmm, the thickness of a microwave radiation plate Even if it uses a thick radiation plate, a dielectric is not inserted in the waveguide of the microwave from a microwave oscillator to the dielectric window for microwave transparency so that microwave can emanate efficiently. It is made for the interior of a waveguide to be in an atmospheric condition, and the antenna means devised so that the guide wave length in an antenna might be made longer than before is used. By performing plasma treatment using such an antenna means, the instability of the plasma by distortion of a microwave radiation plate is canceled, and an extremely stable process can be performed. Moreover, structure is simplified and it is necessary to use neither the Teflon (trademark) for supporting the expensive plate made from a ceramic with which it worries about breakage, and the inner shaft of a coaxial tube, nor the insulator of the ceramics. Therefore, the plasma treatment equipment of this invention is producible in a short period with simple structure.

[0020] The microwave plasma treatment approach of this invention is an antenna means which there is no dielectric plate in the above-mentioned processor, i.e., the interior, and is in an atmospheric condition, and the pair of the slot from which the sense differs mutually is performed using microwave plasma treatment equipment equipped with an antenna means to have the microwave radiation plate with which only two or more sets of round is arranged circularly. The gas pressure in the processing container in this case is 0.1Pa - 1000Pa, and, as for the frequency of the microwave impressed to an electrode, it is desirable that it is 2GHz - 10GHz. Gas pressure is less than 0.1Pa, and if it exceeds 1000Pa, discharge starting and maintenance will become difficult. Moreover, the plasma consistency of the request by a frequency being less than 2GHz is not obtained, but if it exceeds 10GHz, the facility for power

amplification will become large-scale, and also difficulty is in the handling.
[0021]
[Embodiment of the Invention] Hereafter, the microwave plasma treatment equipment concerning the gestalt of operation of this invention is explained with reference to drawing 1 , and 2, 4, 5 and 6. In the plasma treatment equipment for semi-conductor substrates with which microwave was used for drawing 1 as an example of the gestalt of operation of this invention As an antenna means to introduce microwave, the interior of the body of an antenna is a cavity. Only a round is arranged at two or more set round shape (annular), and ** A of the rectangle slot of sense which is different to a microwave radiation plate is the sectional view showing the configuration of the equipment with which the thickness of a radiation plate uses the thing of predetermined thickness (for example, 1.0mm). Drawing 2 shows an example of the slot pattern which was able to be opened in the microwave radiation plate. Drawing 4 -6 show the microwave plasma treatment equipment concerning the gestalt of another operation of this invention.
[0022] In drawing 1 , a processing container for 101 to perform plasma treatment and 102 A coaxial waveguide converter and an antenna means, pair 103of rectangle slot of sense from which 103 differs a (b) (slot pair 103a shown in drawing 2 --) The microwave radiation plate with which 103b is arranged only for a round two or more set annular, The plasma formed in the substrate upper part of microwave electric field in order that 104 might perform the dielectric window for microwave transparency and 105 might perform etching and membrane formation, The magnetron to which 106 oscillates microwave, and 107 An isolator, 108 a waveguide and 110 for a tuner and 109 The supply means of the gas for plasma formation, The pressure regulating valve to which 111 adjusts an exhaust air pump and 112 adjusts the pressure in a container 101, An RF generator for the substrate with which 113 is carried out in plasma treatment, the electrode with which 114 holds a substrate, and 115 to impress a RF to the substrate electrode 114 and a substrate 113 if needed, and 116 are the adjustment machines for taking impedance adjustment of a RF. All the waveguides of microwave until a dielectric etc. is not inserted in the waveguide of microwave until it results [from a waveguide 109] in the microwave radiation plate 103 and it results in a dielectric window 104 are ambient conditions. Moreover, the microwave radiation plate 103 is using the thing of thickness (for example, 1mm) predetermined in thickness. The ring-like sleeve 117 is formed in the part which is separated from the periphery section of a dielectric window 104, i.e., a center section, so that a plasma excitation field may not contact the surface of metal of a direct-processing vessel wall.
[0023] The outline about the plasma treatment approach hereafter performed using the equipment shown in drawing 1 and 2 is explained. In the equipment of the gestalt of this operation, the gas for exciting the plasma 105 with the gas supply means 110 is supplied in the processing container 101, a raw material and reaction secondary generation gas are exhausted by the exhaust air pump system 111, the inside of a container 101 is made reduced pressure, and a pressure regulating valve 112 adjusts the process pressure in a container 101. The microwave oscillated and amplified with the microwave power source (magnetron) 106 is introduced into the antenna means 102 through a tuner 108, and is emitted from the rectangle slots 103a and 103b which were able to be opened in the microwave radiation plate 103. Although a reflected wave is returned to a container 101 side by the tuner 108 at this time, about the reflected wave which cannot be adjusted, it absorbed with the isolator 107, and has prevented returning to a magnetron 106. The microwave emitted through Slots 103a and 103b from the microwave radiation plate 103 is introduced inside the container 101 under a vacuum ambient atmosphere through a dielectric window 104, and forms the plasma 105 in a container 101 by the electromagnetic field which this microwave makes.
[0024] If the consistency of the formed plasma 105 exceeds the cut-off consistency of microwave near the dielectric window 104, the trespass length of microwave will become several mm, a part of energy will be absorbed by the plasma 105 in the range of several mm in the plasma, and the remainder will be reflected. Although the density distribution of the generated plasma 105 can be adjusted to homogeneity at a flat surface depending on a slot pattern, it depends for it also on the pressure in the processing container 101 at that time, or the configuration of a dielectric window 104 greatly. Thus, by diffusion, the generated plasma 105 can

reach to a substrate 113, and can perform desired plasma treatment to a substrate 113.
[0025] Next, the plasma treatment equipment which is the gestalt of another operation of this invention is explained. In the plasma treatment equipment which is another example of the gestalt of operation of this invention shown in drawing 4 , in the field of a concentric circle, i.e., the field from the core of a circular dielectric window to the predetermined equal distance, heights (diameter: D4) are prepared in the front face by the side of atmospheric air (microwave installation side) as a dielectric window 404 which constitutes the introductory aperture of microwave, and the dielectric window which changed the thickness of the part is used. The pattern of a slot pair is the same configuration as what is shown in drawing 2 , and other configurations are the same configurations as what is shown in drawing 1 , and especially about the sign in drawing 4 , unless it refuses, the same sign as drawing 1 shows the same configuration.
[0026] The dielectric window 404 which is an introductory aperture of microwave may be produced from the thing of the construction material described below like the dielectric window 104 shown in drawing 1 . When using a quartz plate with a thickness of 50mm, in the field of the range (D4) to phi= 95mm, the atmospheric-air side of a dielectric window 404 is used as a convex type, and thickness for the convex part is set to 60mm. For example, the thickness of the field where the radius of a substrate is located in right above [of it] in the field of the range (D4x1/2) from 0mm to 47.5mm is set to 60mm, and, as for the thickness of the dielectric window in right above [of a diameter (Dw)200mm silicon substrate], the thickness in other fields is set to 50mm.
[0027] In the plasma treatment equipment which is another example of the gestalt of operation of this invention shown in drawing 5 , as a dielectric window 504 which constitutes the introductory aperture of microwave, heights (diameter: D5) are prepared in the front face by the side of a vacuum at reverse, and the dielectric window which changed the thickness of the part is used with the case of drawing 4 in the field of a concentric circle, i.e., the field from the core of a dielectric window to the predetermined equal distance. The pattern of a slot pair is the same configuration as what is shown in drawing 2 , and other configurations are the same configurations as what is shown in drawing 1 , and especially about the sign in drawing 5 , unless it refuses, the same sign as drawing 1 shows the same configuration.
[0028] The dielectric window 504 which is an introductory aperture of microwave may be produced from the thing of the construction material described below like the dielectric window 104 shown in drawing 1 . When using a quartz plate with a thickness of 44mm, the vacuum side of a dielectric window 504 is used as a convex type in the field of the range (D5) to phi= 60mm, and thickness for the convex part is set to 60mm. For example, the thickness of the field where the radius of a substrate is located in right above [of it] in the field of the range (D5x1/2) from 0mm to 30mm is set to 60mm, and, as for the thickness of the dielectric window in right above [of a diameter (Dw)200mm silicon substrate], the thickness in other fields is set to 44mm. Moreover, in the field (D5x1/2) from 0mm to 30mm, the radius of a substrate sets distance (L52) from a substrate to a dielectric plate to 40mm, and has set the distance (L51) to 56mm in other fields.
[0029] In the plasma treatment equipment which is still more nearly another example of the gestalt of operation of this invention shown in drawing 6 As a dielectric window 604 which constitutes the introductory aperture of microwave, the field of a concentric circle, That is, it is processed so that a crevice may be established in the front face by the side of microwave installation on the front face by the side of heights and a vacuum in the field from the core of a dielectric window to the predetermined equal distance, and the dielectric window constituted so that the thickness of the dielectric window itself might turn into the same thickness in every field is used. The pattern of a slot pair is the same configuration as what is shown in drawing 2 , and other configurations are the same configurations as what is shown in drawing 1 , and especially about the sign in drawing 6 , unless it refuses, the same sign as drawing 1 shows the same configuration.
[0030] The dielectric window 604 which is an introductory aperture of microwave may be produced from the thing of the construction material described below like the dielectric window

104 shown in drawing 1 . When using a quartz plate with a thickness of 50mm, the vacuum side of a dielectric window 604 is made into a concave in the field of the range (D6) to phi= 60mm. Diameter (Dw) from a substrate 613 about the distance to the dielectric window in right above [of a 200mm substrate] The radius of a substrate sets the distance (L62) to 65mm in the field of the range (D6) from 0mm to 30mm, and has set the distance (L61) to 60mm in other fields. Although the pressure in the above-mentioned plasma treatment container changes with process conditions, generally it can acquire preferably 0.1Pa - 1000Pa of desired effectiveness in the range of 5Pa - 1000Pa. As for the distance (L11, L41, L51, L52, L61, L62) of the underside of a dielectric window, and the top face of a substrate, it is desirable to make it the range of 30mm - 120mm generally with relation, such as a plasma consistency, an oxidation rate, and thickness distribution homogeneity.

[0031] As described above, when changing the thickness of a dielectric window within the limits of predetermined, it is desirable to make the thickness into about lambdag of the wavelength (lambdag) of the microwave in a dielectric / 4. Since field strength of microwave is ****(ed) according to the situation of the standing wave which exists there, if a center section is the optimal thickness, in the thin periphery section, a plasma consistency will become low. This is because field strength does not necessarily become strong in the thin part only by making thickness of a dielectric window thin selectively. Therefore, the thing [as / in this invention] which the thickness of a center section is specified and is established for the level difference of lambdag/4 of the wavelength of the microwave in a dielectric is effective. Even if arranged in the shape of [of a concentric circle] a ring, the range which gives the range or level difference which changes the thickness of a dielectric window was distributed suitably, and may be arranged.

[0032] In order to choose suitably from within the limits of 2GHz - 10GHz the frequency of the microwave supplied in order to generate the plasma of high density generally and to make it the plasma consistency [directly under] of a dielectric window reach the cut-off consistency of microwave, it is good to choose charge power from within the limits of 1 W/cm2 - 5 W/cm2 suitably preferably to the area under a dielectric window, and to perform a process. Although it changes as process gas with each processes, such as formation of deposition film (an insulator layer, the semi-conductor film, metal membrane, etc.), formation of the thin films (a silicon system semi-conductor thin film, a silicon compound system thin film, a metal thin film, metallic-compounds thin film, etc.) by the CVD method, etching on the front face of a substrate, ashing clearance of the organic component on a substrate front face, oxidation treatment on the front face of a substrate, and cleaning of the organic substance on the front face of a substrate, various well-known gas can be chosen suitably and can be used. for example, one or more kinds of well-known gas -- the inside of a process -- at least -- a total -- what is necessary is just to introduce more than 8.5x10-2 Pa-m3/sec

[0033] What is necessary is just to choose it from within the limits of -40 degrees C - 600 degrees C suitably generally, although the support stage temperature of a substrate changes with each processes, such as etching and membrane formation. Especially the substrate made into a processing object is not restricted, for example, not only a semi-conductor substrate but a glass substrate, a plastic plate, an AlTiC substrate, etc. can be used for it. As a dielectric which constitutes the introductory aperture of microwave, a mechanical strength is enough, and especially if dielectric loss is a very small ingredient so that the permeability of microwave may become sufficiently high, it will not be restricted, for example, a quartz, an alumina (sapphire), alumimium nitride, silicon nitride, a carbon fluoride polymer, etc. can be used.

[0034]

[Example] Hereafter, the example of this invention is further explained to a detail with reference to a drawing.

When the antenna means which carried the microwave radiation plate 103 of this invention shown in drawing 2 in the antenna means 102 of the equipment shown in drawing 1 is used, (Example 1) In order to carry out comparative evaluation of the stability of both plasma to generate about the case where the antenna means carrying the conventional microwave radiation plate 303 (slot pairs 303a and 303b) shown in drawing 3 instead of this antenna means

102 is used, Time amount after lighting the plasma until the variation rate of a flash or a big tuner is looked at by the plasma was measured.
[0035] The above-mentioned assessment was performed using the equipment shown in drawing 1 which used the same component except the antenna means which carried the microwave radiation plates 103 and 303, respectively. The OFF of the slot pairs 303a and 303b of 3 rounds of a concentric circle as the disk of an alumina dielectric with a thickness of 4mm inserted in the interior of an antenna and shown in drawing 3 as a conventional antenna means used the microwave radiation plate 303 with a diameter [a certain / of 336mm], and a thickness of 0.3mm. On the other hand, as an antenna of this invention, a dielectric was not inserted in the interior of the antenna means 102, but the OFF of the slot pairs 103a and 103b of 1 round as show the interior to drawing 2 as a layer of air with a thickness of 15mm used the microwave radiation plate 103 with a diameter [a certain / of 336mm], and a thickness of 1mm.
[0036] Putting the plate of a quartz on the substrate electrode 114 as a substrate 113, substrate bias did not impress. 0.5 Pa-m3/sec (300sccm) installation of the Ar gas was carried out by reference condition from the gas supply means 110 at the processing container 101, and the exhaust air pump system 111 and the pressure regulating valve 112 adjusted the pressure in the processing container 101 to 20Pa and 133Pa. After pressure regulation was completed, microwave power was introduced at a stretch with the output of 2.5kW, and the plasma was generated.
[0037] The time amount taken for the plasma generated as mentioned above to become instability is summarized in the following table 2.
(A table 2)

処理容器内圧力	従来型のアンテナ手段	本発明のアンテナ手段
２０Ｐａ	１８秒	８分１０秒
１３３Ｐａ	３５秒	１０分以上

In the case of the antenna means of this invention, the result of a table 2 shows that the stability of the plasma resulting from an antenna is improving substantially.
[0038] (Example 2) In order to compare the effectiveness which introduces the microwave power of an antenna to the plasma, the minimum of the microwave power which plasma ignition takes, and the maintaining-a-discharge power after plasma ignition was investigated using the antenna means of the same conventional type as the case of an example 1, and the antenna means of this invention. Putting the plate of a quartz on the substrate electrode 114 as a substrate 113, substrate bias did not impress. 0.5Pa and m3-/sec (300sccm) installation of the Ar gas was carried out by reference condition from the gas supply means 110 at the processing container 101, and the exhaust air pump system 111 and the pressure regulating valve 112 adjusted the pressure in the processing container 101 to 133Pa. Increasing microwave power, namely, seeing a potentiometer, after pressure regulation was completed, the output is increased until it introduces microwave power gradually from the output of 0.0kW and the plasma lights it, and the discharge-starting power was investigated. Moreover, even after the plasma lit, the output was made to once increase to 2.0kW, and the output in case an output is decreased conversely and discharge disappears after that was investigated.
[0039] The result about the discharge-starting power obtained in this way and the maintaining-a-discharge minimum power is summarized in the following table 3.
(A table 3)

	従来型のアンテナ手段	本発明のアンテナ手段
放電開始電力	４００Ｗ	４００Ｗ
放電維持最小電力	３３０Ｗ	３５０Ｗ

Since in the case of the antenna means of this invention there is almost no inferiority in a discharge property even if compared with the conventional antenna means, the result of a table 3 shows that there is almost no effect (the conventional radiation plate thickness: 0.3mm,

radiation plate thickness of 1.0mm of this invention) which the thickness of a microwave radiation plate increased.
[0040] (Example 3) In the conventional antenna means, the pattern of a microwave radiation plate was the same as that of drawing 3 , and investigated discharge-starting power and the maintaining-a-discharge minimum power like the case of an example 2 about what set only thickness to 1.0mm. Consequently, even if it supplied 2.0kW or more of microwave outputs, discharge did not take place. What [not only] is depended on the effect of reduction of the transparency power by count as only shown with a table 1 from this but since the dielectric is not strictly inserted into the thickness of 1.0mm of a slot, it turns out that microwave is almost covered by the thickness of a microwave radiation plate.
[0041] (Example 4) Kr/O2 plasma is generated using the equipment of drawing 1 and this invention shown in 2, 4, 5, and 6, and measurement of the thickness of the oxide film of the processing wafer after oxidizing a silicon substrate directly is explained. Oxidation treatment of a silicon substrate which first is performed using the equipment shown in drawing 1 and 2 is explained. After installing the dielectric window 104 in the introductory aperture of microwave and setting a silicon substrate 113 in the vacuum processing container 101, microwave was outputted from the magnetron 106, the plasma was generated on condition that the following, and the thickness of the oxide film of the silicon substrate 113 after plasma oxidation was measured by the ellipsometer. In addition, the microwave radiation plate used what is shown in drawing 2 used in the examples 1-3.
[0042] As a dielectric window 104, the quartz plate (a dielectric constant 3.8, dielectric loss <1.0x10-4@2.45GHz) with a diameter [of 380mm (vacuum-housing side: 350mm)] and a thickness of 50mm was installed. microwave -- frequency: -- 2.45GHz -- output: -- it was referred to as 2.5kW (about 2.6W/cm 2), hot plate temperature was maintained at 400 degrees C, distance between the top face of a silicon substrate 113 and the underside of a dielectric window 104 (L11) was set to 60mm, and plasma treatment was performed, without impressing high frequency bias to the silicon substrate 113 on the substrate electrode 114. As gas for plasma excitation, 1.7x10-2 Pa-m3/sec supply of 0.5 Pa-m3/sec and O2 was carried out for Kr, by the pressure regulating valve 112, the pressure in the processing container 101 was adjusted to 133Pa, it discharged for 10 minutes, and plasma oxidation processing of a wafer was performed.
[0043] Moreover, plasma treatment was performed on the same conditions as the above except having adjusted the pressure in the processing container 101 to 80Pa by the pressure regulating valve 112. Consequently, distribution of the thickness of the silicon oxide formed on the substrate became concentric circular mostly. The average thickness of the direction of a path is shown in drawing 7 . In the case of 80Pa, the periphery section on a substrate has thickness thicker than a center section, and drawing 7 shows that the oxidation rate of a center section is quicker in the case of 133Pa to a thing with a quick oxidation rate.
[0044] Next, using the equipment shown in drawing 4 , on the same conditions as the case of the equipment shown in drawing 1 and 2, plasma oxidation processing of the silicon substrate 413 was carried out, and the thickness of an oxide film (oxidation silicone film) was measured by the ellipsometer. Consequently, distribution of the thickness of the silicon oxide formed on the substrate became concentric circular with homogeneity mostly. The average thickness of the direction of a path is shown in drawing 8 . It turns out that that difference is small about this result although the oxidation rate of thickness distribution of the oxide film in 80Pa to the periphery section is still quicker than a center section as compared with drawing 7 , and distribution homogeneity is improved. Furthermore, on the whole, the formation rate of an oxide film is quick. While the power of microwave comes to be efficiently supplied to the plasma by changing the configuration of a dielectric window from this, it turns out that distribution homogeneity is improving. Also in 133Pa, on the whole, the oxidation rate is quick, and it can say that it is the same as that of the case where it is 80Pa.
[0045] Furthermore, using the equipment shown in drawing 5 and 6, on the same conditions as the case of the equipment shown in drawing 1 and 2, plasma oxidation processing of the silicon substrates 513 and 613 was carried out, and the thickness of an oxide film (oxidation silicone

film) was measured by the ellipsometer. Consequently, in the case of the equipment shown in drawing 5 , distribution of the thickness of the silicon oxide formed on the substrate became concentric circular with homogeneity mostly. The average thickness of the direction of a path is shown in drawing 9 . This result is known by that the oxidation rate is [the center section] quick rather than the periphery section at the case of thickness distribution of the oxide film in 80Pa to drawing 7 , and reverse as compared with drawing 7 . This is because the consistency of the plasma to which the radius of a silicon substrate reaches a substrate in the range from 0mm to 30mm since the distance (L52) to a dielectric window (plasma production field) is short is higher than other range (distance: L51). Therefore, the distribution homogeneity of thickness is improvable by the membrane formation rate in the field rising by bringing the distance from the dielectric window underside by the side of a vacuum to a substrate close for every field, and adjusting the distance.

[0046] Moreover, in the case of the equipment shown in drawing 6 , distribution of the thickness of the silicon oxide formed on the substrate became concentric circular with homogeneity mostly. The average thickness of the direction of a path is shown in drawing 10 . It turns out that it is improved in the direction in which the oxidation rate of a center section rises, and homogeneity is going up this result from thickness distribution of the oxide film in 80Pa as compared with drawing 7 . On the other hand, it is improved in the direction in which the oxidation rate of the periphery section rises conversely in 133Pa, and homogeneity is going up. Apparently, although this is contradictory to the above-mentioned result, even if the dielectric window 104 (drawing 1) of a flat-surface configuration is used for it in 133Pa high voltage conditions, it has the inclination which the plasma concentrates on a center section. However, since it is far 5mm compared with the field (distance: L61) of others [center section / substrate / distance / (L62) / to a dielectric window (plasma production field)], it becomes thinner than the range of others [consistency / of the plasma which reaches a substrate], and it is thought that distribution has been improved. On the contrary, although the plasma tends to spread in the low voltage of 80Pa since the plasma consistency is thin, the plasma production in a field concave by making into a concave a part of field which a surface wave generates increases, and it thinks because the stability coupled modes of microwave stopped being influenced easily due to the flow and pressure requirement. Therefore, the breadth of the plasma was stopped, and near distribution came to be acquired when it is high voltage conditions.

[0047] As mentioned above, by performing concavo-convex processing to both sides of a dielectric window for every field, the power of microwave was intentionally centralized on this field, and generation of the homogeneous good plasma with little [and] pressure dependence was attained. Although plasma oxidation processing of the silicon substrate was carried out and the oxide film was formed in the above-mentioned example using drawing 1 and the microwave plasma treatment equipment shown in 2, 4, 5, and 6, processes, such as an improvement and refining of membrane formation, etching, and a film presentation, and ashing, were able to be performed to the substrate which is a processed material in semi-conductor LSI production using well-known thin film formation gas, an etchant gas, ashing gas, etc. using the same plasma treatment equipment.

[0048]

[Effect of the Invention] As explained to the detail above, after taking into consideration the thermal reinforcement and the mechanical strength of a microwave radiation plate according to this invention While using the thing thicker than the conventional thing as a microwave radiation plate So that microwave can emanate efficiently, even if it uses this thick radiation plate Do not insert a dielectric in the waveguide of the microwave from a microwave oscillator to the dielectric window for microwave transparency, and the inside of waveguide is made into an ambient condition. By offering the plasma treatment equipment using the antenna means devised so that the guide wave length in an antenna might be made longer than before, and performing plasma treatment using this equipment The instability of the plasma by distortion of a microwave radiation plate is canceled, and an extremely stable process can be performed. Moreover, structure is simplified and it is necessary to use neither the Teflon which supports the expensive plate made from a ceramic with which it worries about breakage, and the inner shaft of a coaxial

tube, nor the insulator of the ceramics, and according to the plasma treatment equipment of this invention, it is simple structure and this processor can be produced in a short period.

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TECHNICAL FIELD

[Field of the Invention] This invention relates to the plasma treatment approach of using microwave excitation plasma treatment equipment (microwave plasma treatment equipment being called hereafter.) and this equipment. It is plasma equipment which has a microwave radiation antenna for introducing microwave until 0.5W /results in the large power flux density of 2 to 20 W/cm2 cm especially. It is involved in the equipment for plasma processes which can perform improvement and refining of membrane formation, etching, and a film presentation, and ashing at the substrate which is a processed material in semi-conductor LSI production, and the plasma treatment approach using this equipment.

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PRIOR ART

[Description of the Prior Art] In recent years, as for micro processing of a wafer, sheet processing is in use with diameter[of macrostomia]-izing of detailed-izing of the device in Semi-conductor LSI, and a wafer. In the plasma process of CVD in it, or etching, the source of the plasma of DC or high-frequency excitation is used. Moreover, ECR (electron cyclotron resonance) is used in the source of the plasma using microwave. In the case of the plasma excited by the RF or ECR as mentioned above, it was difficult to generate the uniform plasma with the diameter of macrostomia the top to be impressed [of a magnetic field] in order to generate the plasma of high density. Moreover, there were also a problem that carry out sputtering of the chamber wall and metal contamination occurs since plasma potential is as high as about 20eV, and ion irradiation energy [further as opposed to a floating substrate] and the problem of giving a damage to a substrate with 10eV or more since it is high.
[0003] Then, the method with which electron temperature generates the surface wave plasma of low high density also with low plasma potential is developed by introducing microwave into a vacuum ambient atmosphere through a dielectric from a slot, and making strong microwave electric field using antenna means, such as a radial line slot antenna (following: calling RLSA.). For example, with the equipment of a patent [No. 3136054] publication, the dielectric is inserted in the interior of an antenna and it is supposed that the plasma can be generated by emitting circularly-polarized-wave microwave for a slot from a concentric circle or the pattern arranged spirally under a certain regulation, without using a magnetic field efficiently. [many]
[0004] On the other hand, the dielectric window of microwave permeability is not installed in a chamber wall by patent No. 2928577, but the equipment which performs a vacuum seal with the dielectric inside an antenna and the waveguide of an antenna is indicated. "Two or more slits of the shape of a thin line from which the sense differs mutually are arrays in large numbers to the shape of a concentric circle or a swirl" of the slot is carried out, and it shortens guide wave length lambdag inside an antenna with the dielectric inside an antenna. Moreover, by using a magnetic field, it supposes that the plasma is generated by the synergistic effect of microwave and a magnetic field, and working pressure is dramatically made into low voltage with the 10-3Torr base (- 10-1Pa base).

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EFFECT OF THE INVENTION

[Effect of the Invention] As explained to the detail above, after taking into consideration the thermal reinforcement and the mechanical strength of a microwave radiation plate according to this invention While using the thing thicker than the conventional thing as a microwave radiation plate So that microwave can emanate efficiently, even if it uses this thick radiation plate Do not insert a dielectric in the waveguide of the microwave from a microwave oscillator to the dielectric window for microwave transparency, and the inside of waveguide is made into an ambient condition. By offering the plasma treatment equipment using the antenna means devised so that the guide wave length in an antenna might be made longer than before, and performing plasma treatment using this equipment The instability of the plasma by distortion of a microwave radiation plate is canceled, and an extremely stable process can be performed. Moreover, structure is simplified and it is necessary to use neither the Teflon which supports the expensive plate made from a ceramic with which it worries about breakage, and the inner shaft of a coaxial tube, nor the insulator of the ceramics, and according to the plasma treatment equipment of this invention, it is simple structure and this processor can be produced in a short period.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, when the antenna of the above-mentioned conventional technique aiming at inserting a dielectric in the interior of an antenna, shortening guide wave length lambdag, and forming as many slots as possible in a microwave radiation plate, and performing homogeneity and efficient microwave radiation in a field is used, a microwave radiation plate deforms with time with generation of heat and the heat from a substrate side, and there is a problem that the plasma becomes instability. Moreover, when the microwave radiation plate deformed and the clearance was made between the microwave radiation plate and the dielectric inside an antenna, abnormality discharge started by electric-field concentration etc., and there was also a problem of occasionally damaging a dielectric.
[0006] This is because thickness of a microwave radiation plate had to be made very thin with about 0.3mm and heat conduction of the part, a mechanical strength, or the direction of a path got very bad, in order to write guide wave length lambdag short by putting a dielectric into the interior of an antenna and to be made not to worsen a radiation property. Although the antenna which formed the direct thin film in the metallic conductor which the slot for functioning as an antenna opened by technique, such as vacuum evaporationo and plating, was proposed to these problems using dielectrics, such as a ceramic, there was a problem that the film separated according to the difference of the expansion coefficient between the ingredients by heat, and the technical problem was in adhesion. Furthermore, it was what it is hard to use general-purpose also in respect of a manufacturing cost or a delivery date.
[0007] Moreover, there is a problem that equipment will complicate a microwave radiation plate according to problems, such as heat removal, although adhesion or the device which carries out a pressure welding and suppresses deformation is also considered by the dielectric inside an antenna and the microwave transparency aperture by the side of a vacuum housing. To the problem why guide wave length lambdag must use a thin microwave radiation plate (namely, slot of thin thickness) when short as described above, he can understand by calculating the trespass length to a slot and transparency power of microwave. This point is explained below.
[0008] First, the power P which penetrates a slot can be expressed with a degree type (1).
(Formula 1)
P = P0 exp (-t2/delta) .... (1)
Here, they are P0:charge power, the thickness of t:slot, and delta:trespass length. The power P which can penetrate a slot decreases exponentially in proportion to the square of slot thickness so that clearly from a formula (1). Moreover, the trespass length delta is given by the degree type (2).
(Formula 2)

$$\delta = 1/(2\pi\sqrt{(1/2a)^2 - (1/\lambda g)^2}) \quad \cdots\cdots (2)$$

Here, they are the die length of the long side of a:slot, and the guide wave length of lambdag:microwave.
[0009] Moreover, when die-length a of the long side of a slot is or more lambdag/2 in this formula (2), the sign in the root becomes zero or minus. When the die length of a slot long side is longer than the one half of the guide wave length, this means that microwave can transmit power

like a waveguide, however thick the thickness of the slot over the travelling direction of microwave may be. However, in order to control to usually take out power with a flat surface, many less than 1/2 slots of the guide wave length are cut with the antenna which emits microwave at a flat surface like this time by the upstream of the propagation of microwave. In addition, since all power may be made to be emitted to the slot by the side of the lowest style cut by the concentric circle, it is not this limitation.

[0010] From the above formula (1) and (2), when it is a time of guide wave length lambdag being 100mm, and 40mm, it asks for the trespass length when setting die-length a of the long side of a slot to a=(lambdag / 2-0.5) mm, respectively actually, for example. In addition, when an alumina was used as a dielectric, since lambdag was set to about 1/rootepsilon to the wavelength (122mm @ 2.45GHz) of free space, it calculated as lambdag=40mm as follows from becoming about lambdag=40mm actually. - At the time of lambdag=100mm, it is a= 49.5 and is set to delta= 111.8mm. - At the time of lambdag=40mm, it is a= 19.5 and is set to delta= 27.9mm.

[0011] These values are assigned to a formula (1) and the difference in the power transmittivity when changing slot thickness t, respectively is summarized in a table 1. (A table 1)

管内波長	アンテナ	電力透過率（%）			
λg (mm)	内部の材料	t＝0.3	t＝0.5	t＝1.0	t＝3.0
100	なし	99.5	99.1	98.2	94.8
40	アルミナ	97.9	96.5	93.1	80.7

[0012] In case microwave penetrates a slot so that guide wave length lambdag is short in spite of carrying out near of the die length of the long side of a slot to lambdag/2 so that the result of a table 1 may also show (when a dielectric is used), it is greatly influenced of the thickness, and transparency power will decrease extremely, so that slot thickness is thick. Moreover, if the value of die-length a of this slot long side becomes still shorter and trespass length also becomes short, it will come to be further influenced of thickness. In addition, since it does not fill up with the dielectric in the thickness direction of a slot strictly when a dielectric is in the interior of an antenna, wavelength will become long extremely immediately after emitting microwave from a slot, and the effect of thickness is actually predicted to come out further.

[0013] In the conventional technique, the above is [guide wave length lambdag] a reason for having to use a thin slot plate, when short. Even if the technical problem of this invention is to solve the problem of the above-mentioned conventional technique and performs microwave radiation of large power from an antenna means, it is by using an antenna means strong also against thermal deformation and a thermal mechanical strength to offer the microwave plasma treatment equipment which can perform reliable and extremely stable plasma treatment, and the art using this equipment.

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MEANS

[Means for Solving the Problem] The microwave excitation plasma treatment equipment of this invention The exhaust air means for decompressing the inside of a microwave plasma treatment container, and the gas supply means for supplying the gas for exciting the plasma in this processing container, An antenna means to have the microwave radiation plate with which it is the antenna means formed in the microwave installation side side of the dielectric window for microwave transparency prepared in the wall surface of this processing container, and this dielectric window, and the slot was formed, In the microwave plasma treatment equipment constituted so that it may have the microwave generating means formed in the upstream of this antenna means, this dielectric window may be countered and a substrate may be installed in this processing container The interior of this antenna means does not have the dielectric plate inserted in order to shorten wavelength in tubing, and it is in an atmospheric condition, and the pair of the slot from which the sense differs mutually becomes the microwave radiation plate of this antenna means from only two or more sets of round being arranged circularly. More than one are arranged circularly, the pair of such a slot adjoining mutually.
[0015] The microwave radiation plate of this antenna means has the thickness of 0.5mm or more and 3.0mm or less. It is easy to deform thermally with being less than 0.5mm, and a mechanical strength is also low. Moreover, if it exceeds 3.0mm, the radiation property of microwave will worsen. In the microwave plasma treatment equipment of this invention, in order to remove heat efficiently from a microwave radiation plate, it is desirable that a channel is cut on the inner shaft and the body of an antenna of a coaxial tube, and it can be made to carry out to them water cooling and to set board thickness of the microwave radiation plate to about 1.0mm further. Although the distortion by heat stops being able to happen easily since clearance of heat is promoted so that thickness becomes thick, and also reinforcement of a microwave radiation plate increases, the radiation property of microwave will worsen. The optimal thickness is set to about 1.0mm to these both problem. Of course, this optimal thickness changes with guide wave lengths in the charge power (power flux density) of microwave, or an antenna.
[0016] Moreover, generally about [of the guide wave length in an antenna] 1/2 and its width of face of the die length of the slot which was able to be opened in the microwave radiation plate are from 4mm to about 8mm preferably from 2mm to about 8mm. It is because there is a possibility of disturbing the electromagnetic field of the microwave which the effect of crosswise electric field emits when there is a problem that intensity of radiation falls that it is less than 2mm since opening is small and it exceeds 8mm. When tested using the microwave radiation plate which has the slot of 2mm, 4mm, and 6mm width of face, a result by which the thing of 6mm width of face is stabilized most among those was brought.
[0017] According to this invention, as for the dielectric window for microwave transparency, it is desirable to have the ring-like sleeve so that a plasma excitation field may not contact the surface of metal of a direct-processing vessel wall at the periphery section of the field by the side of a processing container. Moreover, the shape of surface type and thickness of the center section may be adjusted in a field, and the dielectric window for microwave transparency may be constituted so that it may have the thickness in which the field of the dielectric window corresponding to the predetermined field of a substrate differed from other fields. A dielectric

window is set again to one field of the field by the side of the processing container, and the fields by the side of microwave installation. [whether it is constituted so that heights may be prepared in the field of the dielectric window corresponding to the predetermined field of a substrate and the thickness of the field of the dielectric window corresponding to the predetermined field of a substrate may become thicker than the thickness of other fields, and] Or a crevice is established also in the field corresponding to heights of a field and the field of an opposite hand in which these heights were prepared, and it may be constituted so that the thickness of the prepared field of these heights and a crevice may become the same as the thickness of other fields.

[0018] Furthermore, a dielectric window prepares a concentric circular level difference in the field by the side of the processing container, it is made for the distance from a substrate front face to the front face of a dielectric window to change with fields of a substrate, and it may be constituted so that the consistency of the plasma to generate may become homogeneity on this substrate. This concentric circular level difference may be discontinuously prepared in the direction of a path of a dielectric window for the diameter of 1/2 wave of integral multiple. Moreover, a dielectric window may have the center-section field which has different thickness from other fields, the field which has heights, and the field which has a concentric circular level difference, and the thickness of these fields may be about [of the wavelength of the microwave in a dielectric] 1/4.

[0019] After considering that the thermal reinforcement and the mechanical strength of a microwave radiation plate described above according to this invention While using 0.5-3.0mm, and 1 desirablemm and a desirable thick thing compared with 0.3 conventionalmm, the thickness of a microwave radiation plate Even if it uses a thick radiation plate, a dielectric is not inserted in the waveguide of the microwave from a microwave oscillator to the dielectric window for microwave transparency so that microwave can emanate efficiently. It is made for the interior of a waveguide to be in an atmospheric condition, and the antenna means devised so that the guide wave length in an antenna might be made longer than before is used. By performing plasma treatment using such an antenna means, the instability of the plasma by distortion of a microwave radiation plate is canceled, and an extremely stable process can be performed. Moreover, structure is simplified and it is necessary to use neither the Teflon (trademark) for supporting the expensive plate made from a ceramic with which it worries about breakage, and the inner shaft of a coaxial tube, nor the insulator of the ceramics. Therefore, the plasma treatment equipment of this invention is producible in a short period with simple structure.

[0020] The microwave plasma treatment approach of this invention is an antenna means which there is no dielectric plate in the above-mentioned processor, i.e., the interior, and is in an atmospheric condition, and the pair of the slot from which the sense differs mutually is performed using microwave plasma treatment equipment equipped with an antenna means to have the microwave radiation plate with which only two or more sets of round is arranged circularly. The gas pressure in the processing container in this case is 0.1Pa - 1000Pa, and, as for the frequency of the microwave impressed to an electrode, it is desirable that it is 2GHz - 10GHz. Gas pressure is less than 0.1Pa, and if it exceeds 1000Pa, discharge starting and maintenance will become difficult. Moreover, the plasma consistency of the request by a frequency being less than 2GHz is not obtained, but if it exceeds 10GHz, the facility for power amplification will become large-scale, and also difficulty is in the handling.

[0021]

[Embodiment of the Invention] Hereafter, the microwave plasma treatment equipment concerning the gestalt of operation of this invention is explained with reference to drawing 1 , and 2, 4, 5 and 6. In the plasma treatment equipment for semi-conductor substrates with which microwave was used for drawing 1 as an example of the gestalt of operation of this invention As an antenna means to introduce microwave, the interior of the body of an antenna is a cavity. Only a round is arranged at two or more set round shape (annular), and ** A of the rectangle slot of sense which is different to a microwave radiation plate is the sectional view showing the configuration of the equipment with which the thickness of a radiation plate uses the thing of predetermined thickness (for example, 1.0mm). Drawing 2 shows an example of the slot pattern which was able

to be opened in the microwave radiation plate. Drawing 4 -6 show the microwave plasma treatment equipment concerning the gestalt of another operation of this invention.

[0022] In drawing 1 , a processing container for 101 to perform plasma treatment and 102 A coaxial waveguide converter and an antenna means, pair 103of rectangle slot of sense from which 103 differs a (b) (slot pair 103a shown in drawing 2 —) The microwave radiation plate with which 103b is arranged only for a round two or more set annular, The plasma formed in the substrate upper part of microwave electric field in order that 104 might perform the dielectric window for microwave transparency and 105 might perform etching and membrane formation, The magnetron to which 106 oscillates microwave, and 107 An isolator, 108 a waveguide and 110 for a tuner and 109 The supply means of the gas for plasma formation, The pressure regulating valve to which 111 adjusts an exhaust air pump and 112 adjusts the pressure in a container 101, An RF generator for the substrate with which 113 is carried out in plasma treatment, the electrode with which 114 holds a substrate, and 115 to impress a RF to the substrate electrode 114 and a substrate 113 if needed, and 116 are the adjustment machines for taking impedance adjustment of a RF. All the waveguides of microwave until a dielectric etc. is not inserted in the waveguide of microwave until it results [from a waveguide 109] in the microwave radiation plate 103 and it results in a dielectric window 104 are ambient conditions. Moreover, the microwave radiation plate 103 is using the thing of thickness (for example, 1mm) predetermined in thickness. The ring-like sleeve 117 is formed in the part which is separated from the periphery section of a dielectric window 104, i.e., a center section, so that a plasma excitation field may not contact the surface of metal of a direct-processing vessel wall.

[0023] The outline about the plasma treatment approach hereafter performed using the equipment shown in drawing 1 and 2 is explained. In the equipment of the gestalt of this operation, the gas for exciting the plasma 105 with the gas supply means 110 is supplied in the processing container 101, a raw material and reaction secondary generation gas are exhausted by the exhaust air pump system 111, the inside of a container 101 is made reduced pressure, and a pressure regulating valve 112 adjusts the process pressure in a container 101. The microwave oscillated and amplified with the microwave power source (magnetron) 106 is introduced into the antenna means 102 through a tuner 108, and is emitted from the rectangle slots 103a and 103b which were able to be opened in the microwave radiation plate 103. Although a reflected wave is returned to a container 101 side by the tuner 108 at this time, about the reflected wave which cannot be adjusted, it absorbed with the isolator 107, and has prevented returning to a magnetron 106. The microwave emitted through Slots 103a and 103b from the microwave radiation plate 103 is introduced inside the container 101 under a vacuum ambient atmosphere through a dielectric window 104, and forms the plasma 105 in a container 101 by the electromagnetic field which this microwave makes.

[0024] If the consistency of the formed plasma 105 exceeds the cut-off consistency of microwave near the dielectric window 104, the trespass length of microwave will become several mm, a part of energy will be absorbed by the plasma 105 in the range of several mm in the plasma, and the remainder will be reflected. Although the density distribution of the generated plasma 105 can be adjusted to homogeneity at a flat surface depending on a slot pattern, it depends for it also on the pressure in the processing container 101 at that time, or the configuration of a dielectric window 104 greatly. Thus, by diffusion, the generated plasma 105 can reach to a substrate 113, and can perform desired plasma treatment to a substrate 113.

[0025] Next, the plasma treatment equipment which is the gestalt of another operation of this invention is explained. In the plasma treatment equipment which is another example of the gestalt of operation of this invention shown in drawing 4 , in the field of a concentric circle, i.e., the field from the core of a circular dielectric window to the predetermined equal distance, heights (diameter: D4) are prepared in the front face by the side of atmospheric air (microwave installation side) as a dielectric window 404 which constitutes the introductory aperture of microwave, and the dielectric window which changed the thickness of the part is used. The pattern of a slot pair is the same configuration as what is shown in drawing 2 , and other configurations are the same configurations as what is shown in drawing 1 , and especially about the sign in drawing 4 , unless it refuses, the same sign as drawing 1 shows the same

configuration.
[0026] The dielectric window 404 which is an introductory aperture of microwave may be produced from the thing of the construction material described below like the dielectric window 104 shown in drawing 1 . When using a quartz plate with a thickness of 50mm, in the field of the range (D4) to phi= 95mm, the atmospheric-air side of a dielectric window 404 is used as a convex type, and thickness for the convex part is set to 60mm. For example, the thickness of the field where the radius of a substrate is located in right above [of it] in the field of the range (D4x1/2) from 0mm to 47.5mm is set to 60mm, and, as for the thickness of the dielectric window in right above [of a diameter (Dw)200mm silicon substrate], the thickness in other fields is set to 50mm.
[0027] In the plasma treatment equipment which is another example of the gestalt of operation of this invention shown in drawing 5 , as a dielectric window 504 which constitutes the introductory aperture of microwave, heights (diameter: D5) are prepared in the front face by the side of a vacuum at reverse, and the dielectric window which changed the thickness of the part is used with the case of drawing 4 in the field of a concentric circle, i.e., the field from the core of a dielectric window to the predetermined equal distance. The pattern of a slot pair is the same configuration as what is shown in drawing 2 , and other configurations are the same configurations as what is shown in drawing 1 , and especially about the sign in drawing 5 , unless it refuses, the same sign as drawing 1 shows the same configuration.
[0028] The dielectric window 504 which is an introductory aperture of microwave may be produced from the thing of the construction material described below like the dielectric window 104 shown in drawing 1 . When using a quartz plate with a thickness of 44mm, the vacuum side of a dielectric window 504 is used as a convex type in the field of the range (D5) to phi= 60mm, and thickness for the convex part is set to 60mm. For example, the thickness of the field where the radius of a substrate is located in right above [of it] in the field of the range (D5x1/2) from 0mm to 30mm is set to 60mm, and, as for the thickness of the dielectric window in right above [of a diameter (Dw)200mm silicon substrate], the thickness in other fields is set to 44mm. Moreover, in the field (D5x1/2) from 0mm to 30mm, the radius of a substrate sets distance (L52) from a substrate to a dielectric plate to 40mm, and has set the distance (L51) to 56mm in other fields.
[0029] In the plasma treatment equipment which is still more nearly another example of the gestalt of operation of this invention shown in drawing 6 As a dielectric window 604 which constitutes the introductory aperture of microwave, the field of a concentric circle, That is, it is processed so that a crevice may be established in the front face by the side of microwave installation on the front face by the side of heights and a vacuum in the field from the core of a dielectric window to the predetermined equal distance, and the dielectric window constituted so that the thickness of the dielectric window itself might turn into the same thickness in every field is used. The pattern of a slot pair is the same configuration as what is shown in drawing 2 , and other configurations are the same configurations as what is shown in drawing 1 , and especially about the sign in drawing 6 , unless it refuses, the same sign as drawing 1 shows the same configuration.
[0030] The dielectric window 604 which is an introductory aperture of microwave may be produced from the thing of the construction material described below like the dielectric window 104 shown in drawing 1 . When using a quartz plate with a thickness of 50mm, the vacuum side of a dielectric window 604 is made into a concave in the field of the range (D6) to phi= 60mm. Diameter (Dw) from a substrate 613 about the distance to the dielectric window in right above [of a 200mm substrate] The radius of a substrate sets the distance (L62) to 65mm in the field of the range (D6) from 0mm to 30mm, and has set the distance (L61) to 60mm in other fields. Although the pressure in the above-mentioned plasma treatment container changes with process conditions, generally it can acquire preferably 0.1Pa - 1000Pa of desired effectiveness in the range of 5Pa - 1000Pa. As for the distance (L11, L41, L51, L52, L61, L62) of the underside of a dielectric window, and the top face of a substrate, it is desirable to make it the range of 30mm - 120mm generally with relation, such as a plasma consistency, an oxidation rate, and thickness distribution homogeneity.

[0031] As described above, when changing the thickness of a dielectric window within the limits of predetermined, it is desirable to make the thickness into about lambdag of the wavelength (lambdag) of the microwave in a dielectric / 4. Since field strength of microwave is ****(ed) according to the situation of the standing wave which exists there, if a center section is the optimal thickness, in the thin periphery section, a plasma consistency will become low. This is because field strength does not necessarily become strong in the thin part only by making thickness of a dielectric window thin selectively. Therefore, the thing [as / in this invention] which the thickness of a center section is specified and is established for the level difference of lambdag/4 of the wavelength of the microwave in a dielectric is effective. Even if arranged in the shape of [of a concentric circle] a ring, the range which gives the range or level difference which changes the thickness of a dielectric window was distributed suitably, and may be arranged.
[0032] In order to choose suitably from within the limits of 2GHz - 10GHz the frequency of the microwave supplied in order to generate the plasma of high density generally and to make it the plasma consistency [directly under] of a dielectric window reach the cut-off consistency of microwave, it is good to choose charge power from within the limits of 1 W/cm2 - 5 W/cm2 suitably preferably to the area under a dielectric window, and to perform a process. Although it changes as process gas with each processes, such as formation of deposition film (an insulator layer, the semi-conductor film, metal membrane, etc.), formation of the thin films (a silicon system semi-conductor thin film, a silicon compound system thin film, a metal thin film, metallic-compounds thin film, etc.) by the CVD method, etching on the front face of a substrate, ashing clearance of the organic component on a substrate front face, oxidation treatment on the front face of a substrate, and cleaning of the organic substance on the front face of a substrate, various well-known gas can be chosen suitably and can be used. for example, one or more kinds of well-known gas — the inside of a process — at least — a total — what is necessary is just to introduce more than 8.5x10-2 Pa-m3/sec
[0033] What is necessary is just to choose it from within the limits of -40 degrees C - 600 degrees C suitably generally, although the support stage temperature of a substrate changes with each processes, such as etching and membrane formation. Especially the substrate made into a processing object is not restricted, for example, not only a semi-conductor substrate but a glass substrate, a plastic plate, an AlTiC substrate, etc. can be used for it. As a dielectric which constitutes the introductory aperture of microwave, a mechanical strength is enough, and especially if dielectric loss is a very small ingredient so that the permeability of microwave may become sufficiently high, it will not be restricted, for example, a quartz, an alumina (sapphire), alumimium nitride, silicon nitride, a carbon fluoride polymer, etc. can be used.

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EXAMPLE

[Example] Hereafter, the example of this invention is further explained to a detail with reference to a drawing.
When the antenna means which carried the microwave radiation plate 103 of this invention shown in drawing 2 in the antenna means 102 of the equipment shown in drawing 1 is used, (Example 1) In order to carry out comparative evaluation of the stability of both plasma to generate about the case where the antenna means carrying the conventional microwave radiation plate 303 (slot pairs 303a and 303b) shown in drawing 3 instead of this antenna means 102 is used, Time amount after lighting the plasma until the variation rate of a flash or a big tuner is looked at by the plasma was measured.
[0035] The above-mentioned assessment was performed using the equipment shown in drawing 1 which used the same component except the antenna means which carried the microwave radiation plates 103 and 303, respectively. The OFF of the slot pairs 303a and 303b of 3 rounds of a concentric circle as the disk of an alumina dielectric with a thickness of 4mm inserted in the interior of an antenna and shown in drawing 3 as a conventional antenna means used the microwave radiation plate 303 with a diameter [a certain / of 336mm], and a thickness of 0.3mm. On the other hand, as an antenna of this invention, a dielectric was not inserted in the interior of the antenna means 102, but the OFF of the slot pairs 103a and 103b of 1 round as show the interior to drawing 2 as a layer of air with a thickness of 15mm used the microwave radiation plate 103 with a diameter [a certain / of 336mm], and a thickness of 1mm.
[0036] Putting the plate of a quartz on the substrate electrode 114 as a substrate 113, substrate bias did not impress. 0.5 Pa-m3/sec (300sccm) installation of the Ar gas was carried out by reference condition from the gas supply means 110 at the processing container 101, and the exhaust air pump system 111 and the pressure regulating valve 112 adjusted the pressure in the processing container 101 to 20Pa and 133Pa. After pressure regulation was completed, microwave power was introduced at a stretch with the output of 2.5kW, and the plasma was generated.
[0037] The time amount taken for the plasma generated as mentioned above to become instability is summarized in the following table 2.
(A table 2)

処理容器内圧力	従来型のアンテナ手段	本発明のアンテナ手段
２０Ｐａ	１８秒	8分１０秒
１３３Ｐａ	３５秒	１０分以上

In the case of the antenna means of this invention, the result of a table 2 shows that the stability of the plasma resulting from an antenna is improving substantially.
[0038] (Example 2) In order to compare the effectiveness which introduces the microwave power of an antenna to the plasma, the minimum of the microwave power which plasma ignition takes, and the maintaining-a-discharge power after plasma ignition was investigated using the antenna means of the same conventional type as the case of an example 1, and the antenna means of this invention. Putting the plate of a quartz on the substrate electrode 114 as a substrate 113,

substrate bias did not impress. 0.5Pa and m3-/sec (300sccm) installation of the Ar gas was carried out by reference condition from the gas supply means 110 at the processing container 101, and the exhaust air pump system 111 and the pressure regulating valve 112 adjusted the pressure in the processing container 101 to 133Pa. Increasing microwave power, namely, seeing a potentiometer, after pressure regulation was completed, the output is increased until it introduces microwave power gradually from the output of 0.0kW and the plasma lights it, and the discharge-starting power was investigated. Moreover, even after the plasma lit, the output was made to once increase to 2.0kW, and the output in case an output is decreased conversely and discharge disappears after that was investigated.

[0039] The result about the discharge-starting power obtained in this way and the maintaining-a-discharge minimum power is summarized in the following table 3.

(A table 3)

	従来型のアンテナ手段	本発明のアンテナ手段
放電開始電力	４００W	４００W
放電維持最小電力	３３０W	３５０W

Since in the case of the antenna means of this invention there is almost no inferiority in a discharge property even if compared with the conventional antenna means, the result of a table 3 shows that there is almost no effect (the conventional radiation plate thickness: 0.3mm, radiation plate thickness of 1.0mm of this invention) which the thickness of a microwave radiation plate increased.

[0040] (Example 3) In the conventional antenna means, the pattern of a microwave radiation plate was the same as that of drawing 3 , and investigated discharge-starting power and the maintaining-a-discharge minimum power like the case of an example 2 about what set only thickness to 1.0mm. Consequently, even if it supplied 2.0kW or more of microwave outputs, discharge did not take place. What [not only] is depended on the effect of reduction of the transparency power by count as only shown with a table 1 from this but since the dielectric is not strictly inserted into the thickness of 1.0mm of a slot, it turns out that microwave is almost covered by the thickness of a microwave radiation plate.

[0041] (Example 4) Kr/O2 plasma is generated using the equipment of drawing 1 and this invention shown in 2, 4, 5, and 6, and measurement of the thickness of the oxide film of the processing wafer after oxidizing a silicon substrate directly is explained. Oxidation treatment of a silicon substrate which first is performed using the equipment shown in drawing 1 and 2 is explained. After installing the dielectric window 104 in the introductory aperture of microwave and setting a silicon substrate 113 in the vacuum processing container 101, microwave was outputted from the magnetron 106, the plasma was generated on condition that the following, and the thickness of the oxide film of the silicon substrate 113 after plasma oxidation was measured by the ellipsometer. In addition, the microwave radiation plate used what is shown in drawing 2 used in the examples 1-3.

[0042] As a dielectric window 104, the quartz plate (a dielectric constant 3.8, dielectric loss <1.0x10-4@2.45GHz) with a diameter [of 380mm (vacuum-housing side: 350mm)] and a thickness of 50mm was installed. microwave -- frequency: -- 2.45GHz -- output: -- it was referred to as 2.5kW (about 2.6W/cm 2), hot plate temperature was maintained at 400 degrees C, distance between the top face of a silicon substrate 113 and the underside of a dielectric window 104 (L11) was set to 60mm, and plasma treatment was performed, without impressing high frequency bias to the silicon substrate 113 on the substrate electrode 114. As gas for plasma excitation, 1.7x10-2 Pa-m3/sec supply of 0.5 Pa-m3/sec and O2 was carried out for Kr, by the pressure regulating valve 112, the pressure in the processing container 101 was adjusted to 133Pa, it discharged for 10 minutes, and plasma oxidation processing of a wafer was performed.

[0043] Moreover, plasma treatment was performed on the same conditions as the above except having adjusted the pressure in the processing container 101 to 80Pa by the pressure regulating valve 112. Consequently, distribution of the thickness of the silicon oxide formed on the

substrate became concentric circular mostly. The average thickness of the direction of a path is shown in drawing 7 . In the case of 80Pa, the periphery section on a substrate has thickness thicker than a center section, and drawing 7 shows that the oxidation rate of a center section is quicker in the case of 133Pa to a thing with a quick oxidation rate.

[0044] Next, using the equipment shown in drawing 4 , on the same conditions as the case of the equipment shown in drawing 1 and 2, plasma oxidation processing of the silicon substrate 413 was carried out, and the thickness of an oxide film (oxidation silicone film) was measured by the ellipsometer. Consequently, distribution of the thickness of the silicon oxide formed on the substrate became concentric circular with homogeneity mostly. The average thickness of the direction of a path is shown in drawing 8 . It turns out that that difference is small about this result although the oxidation rate of thickness distribution of the oxide film in 80Pa to the periphery section is still quicker than a center section as compared with drawing 7 , and distribution homogeneity is improved. Furthermore, on the whole, the formation rate of an oxide film is quick. While the power of microwave comes to be efficiently supplied to the plasma by changing the configuration of a dielectric window from this, it turns out that distribution homogeneity is improving. Also in 133Pa, on the whole, the oxidation rate is quick, and it can say that it is the same as that of the case where it is 80Pa.

[0045] Furthermore, using the equipment shown in drawing 5 and 6, on the same conditions as the case of the equipment shown in drawing 1 and 2, plasma oxidation processing of the silicon substrates 513 and 613 was carried out, and the thickness of an oxide film (oxidation silicone film) was measured by the ellipsometer. Consequently, in the case of the equipment shown in drawing 5 , distribution of the thickness of the silicon oxide formed on the substrate became concentric circular with homogeneity mostly. The average thickness of the direction of a path is shown in drawing 9 . This result is known by that the oxidation rate is [the center section] quick rather than the periphery section at the case of thickness distribution of the oxide film in 80Pa to drawing 7 , and reverse as compared with drawing 7 . This is because the consistency of the plasma to which the radius of a silicon substrate reaches a substrate in the range from 0mm to 30mm since the distance (L52) to a dielectric window (plasma production field) is short is higher than other range (distance: L51). Therefore, the distribution homogeneity of thickness is improvable by the membrane formation rate in the field rising by bringing the distance from the dielectric window underside by the side of a vacuum to a substrate close for every field, and adjusting the distance.

[0046] Moreover, in the case of the equipment shown in drawing 6 , distribution of the thickness of the silicon oxide formed on the substrate became concentric circular with homogeneity mostly. The average thickness of the direction of a path is shown in drawing 10 . It turns out that it is improved in the direction in which the oxidation rate of a center section rises, and homogeneity is going up this result from thickness distribution of the oxide film in 80Pa as compared with drawing 7 . On the other hand, it is improved in the direction in which the oxidation rate of the periphery section rises conversely in 133Pa, and homogeneity is going up. Apparently, although this is contradictory to the above-mentioned result, even if the dielectric window 104 (drawing 1) of a flat-surface configuration is used for it in 133Pa high voltage conditions, it has the inclination which the plasma concentrates on a center section. However, since it is far 5mm compared with the field (distance: L61) of others [center section / substrate / distance / (L62) / to a dielectric window (plasma production field)], it becomes thinner than the range of others [consistency / of the plasma which reaches a substrate], and it is thought that distribution has been improved. On the contrary, although the plasma tends to spread in the low voltage of 80Pa since the plasma consistency is thin, the plasma production in a field concave by making into a concave a part of field which a surface wave generates increases, and it thinks because the stability coupled modes of microwave stopped being influenced easily due to the flow and pressure requirement. Therefore, the breadth of the plasma was stopped, and near distribution came to be acquired when it is high voltage conditions.

[0047] As mentioned above, by performing concavo-convex processing to both sides of a dielectric window for every field, the power of microwave was intentionally centralized on this field, and generation of the homogeneous good plasma with little [and] pressure dependence

was attained. Although plasma oxidation processing of the silicon substrate was carried out and the oxide film was formed in the above-mentioned example using drawing 1 and the microwave plasma treatment equipment shown in 2, 4, 5, and 6, processes, such as an improvement and refining of membrane formation, etching, and a film presentation, and ashing, were able to be performed to the substrate which is a processed material in semi-conductor LSI production using well-known thin film formation gas, an etchant gas, ashing gas, etc. using the same plasma treatment equipment.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The typical sectional view showing the example of 1 configuration of the microwave plasma treatment equipment concerning the gestalt of operation of this invention.
[Drawing 2] The top view showing typically an example of the antenna pattern of the microwave radiation plate used for an antenna means in the microwave plasma treatment equipment concerning this invention.
[Drawing 3] The top view showing typically an example of the antenna pattern of the microwave radiation plate used for the antenna means of a conventional type in the microwave plasma treatment equipment concerning this invention.
[Drawing 4] The typical sectional view showing the configuration of the microwave plasma treatment equipment concerning the gestalt of another operation of this invention.
[Drawing 5] The typical sectional view showing the configuration of the microwave plasma treatment equipment concerning the gestalt of another operation of this invention.
[Drawing 6] The typical sectional view showing the configuration of the microwave plasma treatment equipment concerning the gestalt of still more nearly another operation of this invention.
[Drawing 7] The graph which shows the average thickness of the direction of a path about the silicon oxide formed using the equipment shown in drawing 1 .
[Drawing 8] The graph which shows the average thickness of the direction of a path about the silicon oxide formed using the equipment shown in drawing 4 .
[Drawing 9] The graph which shows the average thickness of the direction of a path about the silicon oxide formed using the equipment shown in drawing 5 .
[Drawing 10] The graph which shows the average thickness of the direction of a path about the silicon oxide formed using the equipment shown in drawing 6 .
[Description of Notations]
101 Body of Plasma Treatment Container 102 Coaxial Waveguide Converter and Antenna
103 Microwave Radiation Plate 104 Dielectric Window for Vacuum Seals
105 Plasma 106 Magnetron
107 Isolator 108 Tuner
109 Waveguide 110 Gas Supply Means
111 Exhaust Air Pump System 112 Pressure Regulating Valve
113 Substrate 103a, 103B Slot
114 Substrate Electrode 115 RF Generator for Substrate Electrodes
116 Adjustment Machine for Substrate Electrodes 117 Sleeve
303 Microwave Radiation Plate 303a, 303B Slot
404 Dielectric **** 413 Substrate
L41 Distance between dielectric ****-substrates Dw Substrate field
D4 Dielectric **** thickness modification field 504 Dielectric ****
513 Substrate L51 Distance between Dielectric ****-Substrates
L52 Distance between dielectric ****-substrates (thickness modification section)
D5 Dielectric **** thickness modification field 604 Dielectric ****

613 Substrate L61 Distance between Dielectric ****-Substrates
L62 Distance between dielectric ****-substrates (configuration modification section)
D6 Dielectric window thickness modification field

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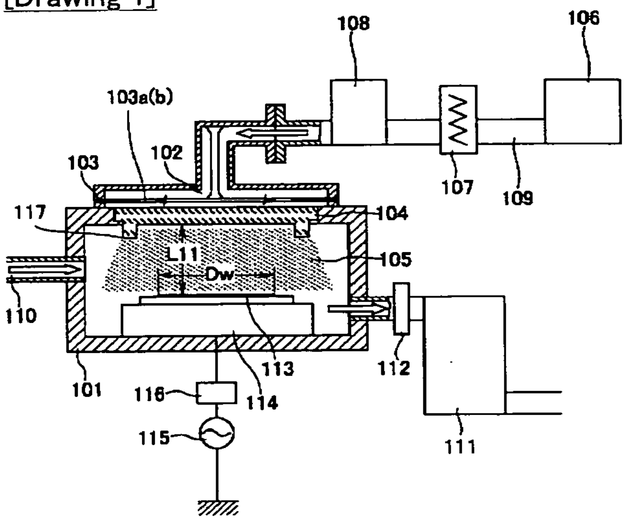
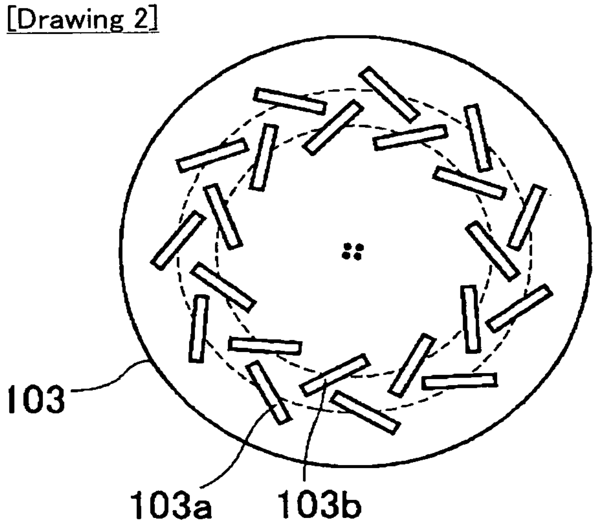
DRAWINGS

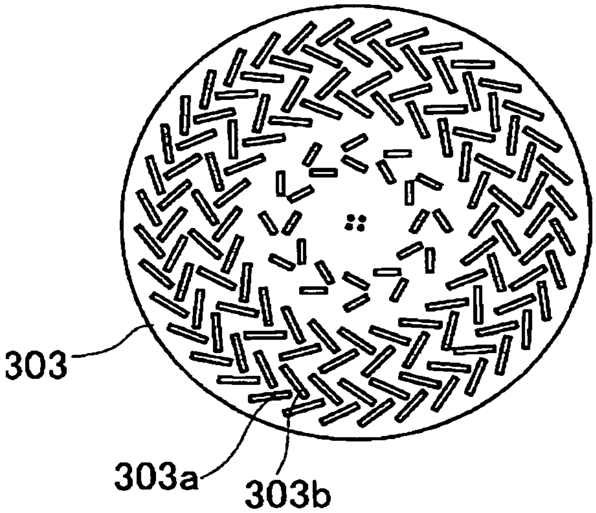
[Drawing 1]



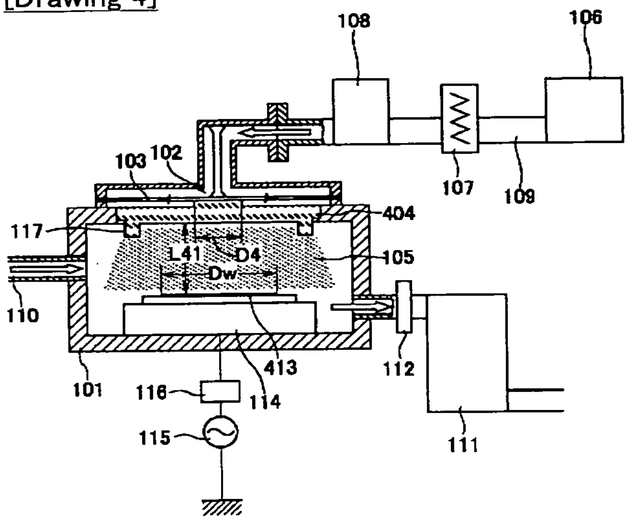
[Drawing 2]



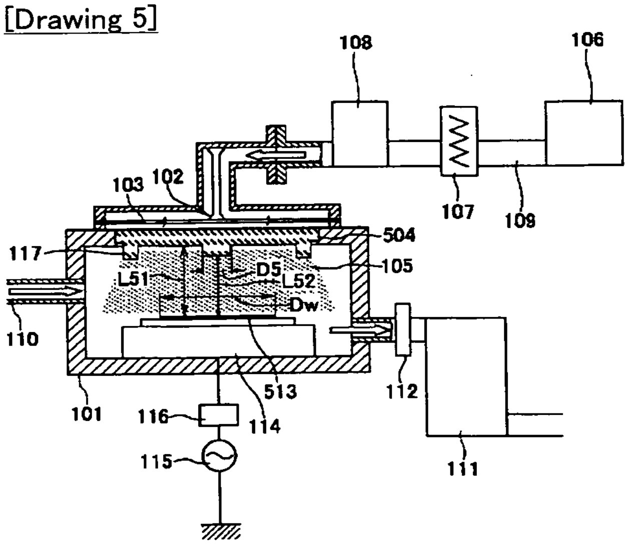
[Drawing 3]



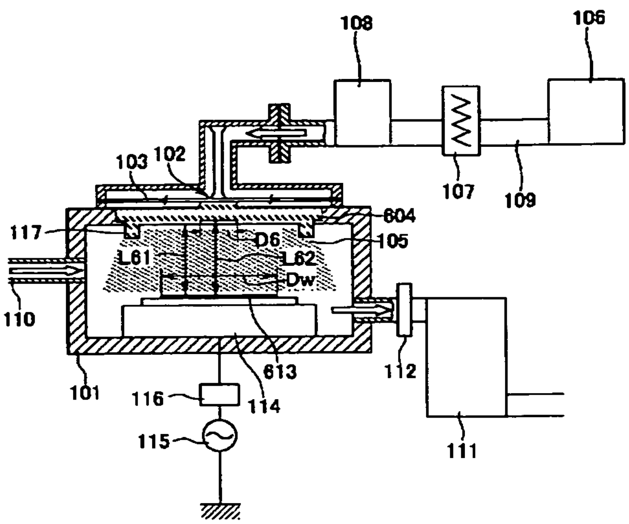
[Drawing 4]



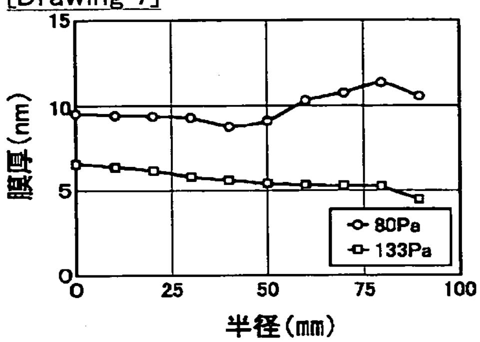
[Drawing 5]



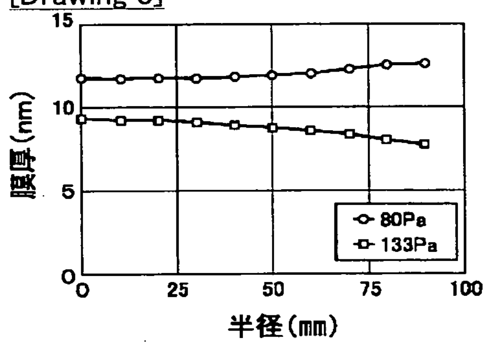
[Drawing 6]



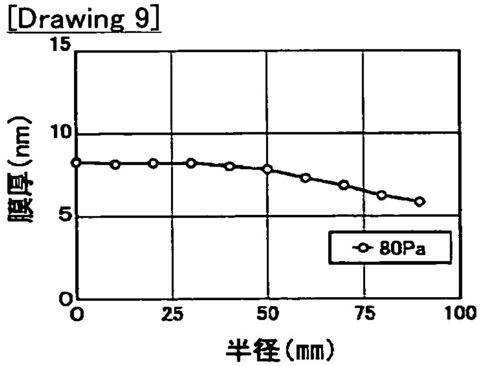
[Drawing 7]



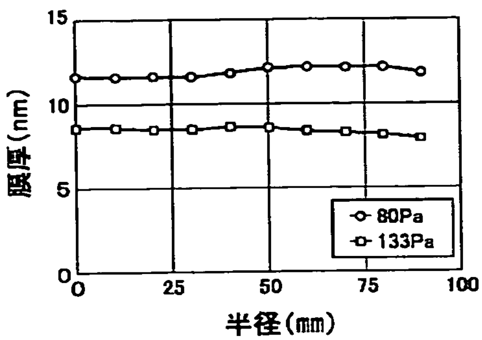
[Drawing 8]



[Drawing 9]



[Drawing 10]



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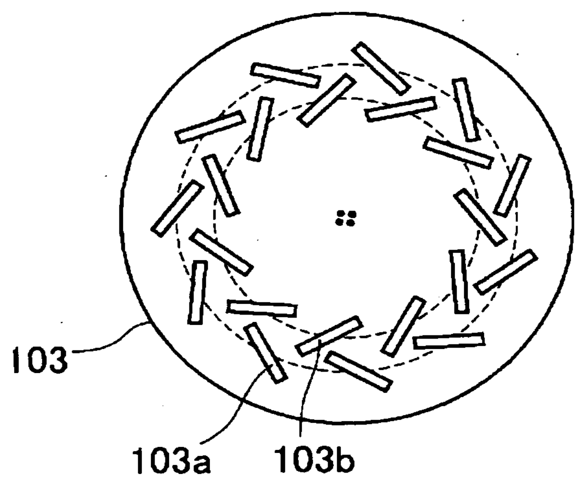
(54)【発明の名称】　マイクロ波プラズマ処理装置および処理方法

(57)【要約】
【課題】　大電力のマイクロ波放射を行っても、熱的な変形や機械的強度に強いアンテナ手段を用いて、信頼性、安定性の高いプラズマ処理を行うことができるマイクロ波プラズマ処理装置および処理方法の提供。
【解決手段】　マイクロ波プラズマ処理装置において、マイクロ波透過用誘電体窓のマイクロ波導入面側に設けられたスロットを有するアンテナ手段として、その内部には管内の波長を短くするために挿入される誘電体板が無く、かつ内部は大気の状態であり、そのマイクロ波放射板には互いに向きの異なるスロットのペアが複数組円形に一周のみ配置されており、マイクロ波放射板の厚さが０．５ｍｍ以上、３．０ｍｍ以下であるように構成されたアンテナ手段を備えていること。



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【特許請求の範囲】

【請求項１】　マイクロ波プラズマ処理容器内を減圧するための排気手段と、該処理容器内にプラズマを励起するためのガスを供給するためのガス供給手段と、該処理容器の壁面に設けられたマイクロ波透過用誘電体窓と、該誘電体窓のマイクロ波導入面側に設けられたアンテナ手段であって、スロットが形成されたマイクロ波放射板を有するアンテナ手段と、該アンテナ手段の上流側に設けられたマイクロ波発生手段とを備え、該誘電体窓に対向して該処理容器内に基板が設置されるように構成されているマイクロ波プラズマ処理装置において、該アンテナ手段の内部は管内の波長を短くするために挿入される誘電体板が無く、かつ大気の状態であり、該アンテナ手段のマイクロ波放射板には、互いに向きの異なるスロットのペアが複数組円形に一周のみ配置されていることを特徴とするマイクロ波プラズマ処理装置。

【請求項２】　前記アンテナ手段のマイクロ波放射板は厚さが０．５ｍｍ以上、３．０ｍｍ以下であることを特徴とする請求項１に記載のマイクロ波プラズマ処理装置。

【請求項３】　前記スロットの長さは管内波長の約１／２とし、その幅は２ｍｍ以上、８ｍｍ以下であることを特徴とする請求項１または２に記載のマイクロ波プラズマ処理装置。

【請求項４】　前記誘電体窓は、前記処理容器側の面の外周部に、プラズマ励起領域が直接処理容器壁の金属表面と接触しないように、リング状のスリーブを有していることを特徴とする請求項１～３のいずれかに記載のマイクロ波プラズマ処理装置。

【請求項５】　前記誘電体窓は、その中央部の表面形状や厚さが面内調整されて、前記基板の所定領域に対応する誘電体窓の領域がその他の領域と異なった厚さを有するように構成されているものであることを特徴とする請求項１～４のいずれかに記載のマイクロ波プラズマ処理装置。

【請求項６】　前記誘電体窓は、その処理容器側の面およびマイクロ波導入側の面のうちの一方の面において、前記基板の所定領域に対応する誘電体窓の領域に凸部を設けて、該基板の所定領域に対応する誘電体窓の領域の厚さがその他の領域の厚さより厚くなるように構成されたものであるか、または、該凸部の設けられた面と反対側の面の該凸部対応領域にも凹部を設けて、該凸部と凹部との設けられた領域の厚さがその他の領域の厚さと同じになるように構成されたものであることを特徴とする請求項１～４のいずれかに記載のマイクロ波プラズマ処理装置。

【請求項７】　前記誘電体窓は、その処理容器側の面に同心円状の段差を設けて、前記基板表面から該誘電体窓の表面までの距離が基板の領域によって異なるようにし、生成するプラズマの密度が該基板上で均一になるように構成されたものであることを特徴とする請求項１～４のいずれかに記載のマイクロ波プラズマ処理装置。

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【請求項８】　前記誘電体窓の同心円状の段差が、該誘電体窓の径方向に１／２波長の整数倍の直径で不連続に設けられていることを特徴とする請求項７記載のマイクロ波プラズマ処理装置。

【請求項９】　前記誘電体窓は、他の領域と異なった厚さを有する中央部領域や、凸部を有する領域や、同心円状の段差を有する領域を有し、これらの領域の厚さが誘電体内のマイクロ波の波長の１／４程度であることを特徴とする請求項１～８のいずれかに記載のマイクロ波プラズマ処理装置。

【請求項１０】　マイクロ波プラズマ処理容器内にガス供給手段によってプラズマを励起するための原料ガスを供給し、排気ポンプにより原料及び反応副生成ガスを排気して容器内を減圧にし、マイクロ波発生手段により発振、増幅せしめたマイクロ波をスロットの形成されたマイクロ波放射板を有するアンテナ手段に導入してスロットを通して放射し、放射されたマイクロ波をマイクロ波透過窓を介して減圧導入ガス雰囲気下の該処理容器内へ導入し、このマイクロ波の作る電磁界によって処理容器内にプラズマを生成し、該誘電体窓に対向して設けられた基板をマイクロ波プラズマ処理することからなるプラズマ処理方法であって、請求項１～９のいずれかに記載のマイクロ波プラズマ処理装置を用いてプラズマ処理を行うことを特徴とするマイクロ波プラズマ処理方法。

【請求項１１】　前記処理容器内のガスの圧力は０．１Ｐａ～１０００Ｐａであり、電極に印加されるマイクロ波の周波数は２ＧＨｚ～１０ＧＨｚであることを特徴とする請求項１０に記載のマイクロ波プラズマ処理方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、マイクロ波励起プラズマ処理装置（以下、マイクロ波プラズマ処理装置と称す。）およびこの装置を用いるプラズマ処理方法に係わり、特に０．５Ｗ／ｃｍ^{2}から２０Ｗ／ｃｍ^{2}の大電力密度に至るまでのマイクロ波を導入するためのマイクロ波放射アンテナを有するプラズマ装置であって、半導体ＬＳＩ作製における被処理物である基板に成膜、エッチング、膜組成の改善・改質、アッシングを行うことのできるプラズマプロセス用装置、およびこの装置を用いるプラズマ処理方法に係わる。

【０００２】

【従来の技術】近年、半導体ＬＳＩにおけるデバイスの微細化、ウェーハの大口径化に伴い、ウェーハの微細加工は枚葉処理が主流になっている。その中のＣＶＤやエッチングのプラズマプロセスではＤＣや高周波励起のプラズマ源が用いられている。また、マイクロ波を用いたプラズマ源ではＥＣＲ（電子サイクロトロン共鳴）が用いられている。上記のように高周波やＥＣＲで励起され

たプラズマの場合、高密度のプラズマを生成するためには磁場の印加が必要である上、大口径で均一なプラズマを生成することが困難であった。また、プラズマ電位が約２０ｅＶと高いためにチャンバ壁をスパッタリングして金属汚染が発生するという問題や、さらに、フローティング基板に対するイオン照射エネルギーも１０ｅＶ以上と高いために基板にダメージを与えるといった問題もあった。

【０００３】そこで、ラジアルラインスロットアンテナ（以下：ＲＬＳＡと称す。）などのアンテナ手段を用い、スロットから誘電体を介してマイクロ波を真空雰囲気中に導入し、強いマイクロ波電界を作り出すことによって、電子温度が低くプラズマポテンシャルも低い高密度の表面波プラズマを生成する方式が開発されている。例えば、特許第３１３６０５４号に記載の装置では、アンテナの内部に誘電体が挿入されており、スロットをある規則で同心円または渦巻状に多数配置したパターンから円偏波マイクロ波を放射することで、効率的に磁場を用いることなくプラズマが生成できるとされている。

【０００４】一方、特許第２９２８５７７号には、マイクロ波透過性の誘電体窓がチャンバ壁に設置されておらず、アンテナ内部の誘電体とアンテナの導波管とで真空シールを行う装置が記載されている。スロットは、「複数の互いに向きの異なる細線状のスリットが同心円又は渦巻状に多数配列」されており、アンテナ内部の誘電体によってアンテナ内部の管内波長λｇを短くしている。また、磁場を用いることで、マイクロ波と磁場との相乗効果でプラズマを生成するとし、動作圧力を10^{-3} Ｔｏｒｒ台（～10^{-1} Ｐａ台）と非常に低圧にしている。

【０００５】

【発明が解決しようとする課題】しかしながら、アンテナ内部に誘電体を挿入して管内波長λｇを短くし、かつマイクロ波放射板に出来るだけ多くのスロットを形成して面内で均一かつ効率的なマイクロ波放射を行うことを目的とした上記従来技術のアンテナを用いると、マイクロ波放射板が発熱および基板側からの熱により経時的に＊変形し、プラズマが不安定になるといった問題がある。また、マイクロ波放射板が変形して、マイクロ波放射板とアンテナ内部の誘電体との間に隙間が出来ると、電界集中などによって異常放電がおこり、時には誘電体を破損してしまうといった問題もあった。

【０００６】これは、アンテナ内部に誘電体を入れることで管内波長λｇを短くしたため、放射特性を悪くしないようにするには、マイクロ波放射板の厚さを０．３ｍｍ程度と非常に薄くしなければならず、その分、機械的強度や径方向の熱伝導が非常に悪くなったからである。これらの問題に対しては、セラミックなどの誘電体を用いて、アンテナとして機能するためのスロットの開いた金属導体に蒸着やメッキなどの手法によって直接薄膜を形成したアンテナなども提案されているが、熱による材料間の膨張係数の差によって膜が剥れるといった問題があり、密着性に課題があった。さらに、製造コストや納期の面でも汎用的に使い難いものであった。

【０００７】また、マイクロ波放射板をアンテナ内部の誘電体と真空容器側のマイクロ波透過窓とに接着もしくは圧接して変形を抑える工夫も考えられるが、熱除去等の問題によって装置が複雑化してしまうという問題がある。上記したように管内波長λｇが短いときになぜ薄いマイクロ波放射板（すなわち、薄い厚さのスロット）を用いなければならないかという問題に対しては、マイクロ波のスロットに対する侵入長と透過電力を計算することで理解できる。この点について、以下説明する。

【０００８】まず、スロットを透過する電力Ｐは次式（１）であらわすことができる。

（式１）

$$P = P_0 \exp(-t^2/\delta) \quad \cdots\cdots (1)$$

ここで、P_0：投入電力、ｔ：スロットの厚さ、δ：侵入長である。式（１）から明らかなように、スロットを透過できる電力Ｐはスロット厚さの自乗に比例して指数関数的に減少する。また、侵入長δは次式（２）で与えられる。

（式２）

$$\delta = 1/(2\pi\sqrt{(1/2a)^2 - (1/\lambda g)^2}) \quad \cdots\cdots (2)$$

ここで、ａ：スロットの長辺の長さ、λｇ：マイクロ波の管内波長である。

【０００９】また、この式（２）においてスロットの長辺の長さａがλｇ／２以上の時、ルート内の符号はゼロ又はマイナスになる。このことは、スロット長辺の長さが管内波長の半分よりも長い時には、マイクロ波の進行方向に対するそのスロットの厚さがいくら厚くても、マイクロ波は導波管のようにパワーを伝達することが出来るということを意味している。しかし、今回のような平面でマイクロ波を放射するアンテナでは、通常パワーを平面で出すように制御するため、管内波長の１／２未満のスロットがマイクロ波の伝播方向の上流側に多数切られている。なお、同心円に切られた最下流側のスロットは全てのパワーを放射するようにされることがあるので、この限りではない。

【００１０】以上の式（１）、（２）から、例えば、管内波長λｇが１００ｍｍの時と４０ｍｍの時に、スロットの長辺の長さａをそれぞれ、ａ＝（λｇ／２－０．５）ｍｍとしたときの侵入長を実際に求めてみる。なお、誘電体としてアルミナを用いた場合、λｇは自由空間の波長（１２２ｍｍ@２．４５ＧＨｚ）に対して約$1/\sqrt{\varepsilon}$となるため、実際にはλｇ＝４０ｍｍ程度になることから、以下のようにλｇ＝４０ｍｍとして計算を行った。・λｇ＝１００ｍｍのとき、ａ＝４９．５であ

り、δ＝１１１．８ｍｍとなる。・λｇ＝４０ｍｍのとき、ａ＝１９．５であり、δ＝２７．９ｍｍとなる。

【００１１】これらの値を式（１）に代入して、それぞ＊れスロット厚さｔを変えた時の電力透過率の違いを表１にまとめる。（表１）

管内波長 λｇ（ｍｍ）	アンテナ 内部の材料	電力透過率（％）			
		ｔ＝０．３	ｔ＝０．５	ｔ＝１．０	ｔ＝３．０
１００	なし	９９．５	９９．１	９８．２	９４．８
４０	アルミナ	９７．９	９６．５	９３．１	８０．７

【００１２】表１の結果からもわかるように、スロットの長辺の長さをλｇ／２に近くしているにもかかわらず、管内波長λｇが短いほど（誘電体を用いた場合）、マイクロ波がスロットを透過する際、その厚さの影響を大きく受け、スロット厚さが厚いほど透過電力が極端に減少してしまう。また、このスロット長辺の長さａの値がさらに短くなり侵入長も短くなると、さらに厚さの影響を受けるようになる。この他、アンテナ内部に誘電体がある場合、誘電体は厳密にはスロットの厚さ方向に充填されていないので、マイクロ波はスロットから放射された直後に極端に波長が長くなることになり、実際には厚さの影響がさらに出てくると予測される。

【００１３】以上が、従来技術において、管内波長λｇが短いときに、薄いスロット板を用いなければならない理由である。本発明の課題は、上記従来技術の問題を解決することにあり、アンテナ手段から大電力のマイクロ波放射を行っても、熱的な変形や機械的強度にも強いアンテナ手段を用いることにより、信頼性、安定性の高いプラズマ処理を行うことができるマイクロ波プラズマ処理装置およびこの装置を用いる処理方法を提供することにある。

【００１４】

【課題を解決するための手段】本発明のマイクロ波励起プラズマ処理装置は、マイクロ波プラズマ処理容器内を減圧するための排気手段と、該処理容器内にプラズマを励起するためのガスを供給するためのガス供給手段と、該処理容器の壁面に設けられたマイクロ波透過用誘電体窓と、該誘電体窓のマイクロ波導入面側に設けられたアンテナ手段であって、スロットが形成されたマイクロ波放射板を有するアンテナ手段と、該アンテナ手段の上流側に設けられたマイクロ波発生手段とを備え、該誘電体窓に対向して該処理容器内に基板が設置されるように構成されているマイクロ波プラズマ処理装置において、該アンテナ手段の内部は管内の波長を短くするために挿入される誘電体板が無く、かつ大気の状態であり、該アンテナ手段のマイクロ波放射板には、互いに向きの異なるスロットのペアが複数組円形に一周のみ配置されていることからなる。このようなスロットのペアが互いに隣接しつつ複数個円形に配置されている。

【００１５】該アンテナ手段のマイクロ波放射板は、０．５ｍｍ以上、３．０ｍｍ以下の厚さを有するものである。０．５ｍｍ未満であると熱的に変形しやすく、機械的強度も低い。また、３．０ｍｍを超えるとマイクロ波の放射特性が悪くなる。本発明のマイクロ波プラズマ処理装置において、マイクロ波放射板から熱を効率よく取り除くために、同軸管の内軸やアンテナ本体に水路を切って、水冷できるようにすること、さらにそのマイクロ波放射板の板厚を１．０ｍｍ程度にすることが好ましい。マイクロ波放射板は、厚さが厚くなるほど熱の除去が促進されるほか、強度も増すため、熱による歪みは起こりにくくなるが、マイクロ波の放射特性が悪くなってしまう。これら両者の問題に対して最適な厚さが１．０ｍｍ程度となる。もちろんこの最適な厚さは、マイクロ波の投入電力（電力密度）やアンテナ内の管内波長によって異なってくる。

【００１６】また、マイクロ波放射板に開けられたスロットの長さは、アンテナ内の管内波長の１／２程度、その幅は、一般的に２ｍｍから８ｍｍ程度まで、好ましくは４ｍｍから８ｍｍ程度までである。２ｍｍ未満であると開口が小さいため放射強度が低下するという問題があり、８ｍｍを超えると幅方向の電界の影響が放射するマイクロ波の電磁界を乱してしまう恐れがあるからである。２ｍｍ、４ｍｍ、６ｍｍ幅のスロットを有するマイクロ波放射板を用いてテストを行ったところ、そのうち６ｍｍ幅のものが最も安定する結果となった。

【００１７】本発明によれば、マイクロ波透過用誘電体窓は、処理容器側の面の外周部に、プラズマ励起領域が直接処理容器壁の金属表面と接触しないように、リング状のスリーブを有していることが好ましい。また、マイクロ波透過用誘電体窓は、その中央部の表面形状や厚さが面内調整されて、基板の所定領域に対応する誘電体窓の領域がその他の領域と異なった厚さを有するように構成されているものであっても良い。誘電体窓はまた、その処理容器側の面およびマイクロ波導入側の面のうちの一方の面において、基板の所定領域に対応する誘電体窓の領域に凸部を設けて、基板の所定領域に対応する誘電体窓の領域の厚さがその他の領域の厚さより厚くなるように構成されたものであるか、または、該凸部の設けられた面と反対側の面の凸部対応領域にも凹部を設けて、該凸部と凹部との設けられた領域の厚さがその他の領域の厚さと同じになるように構成されたものであっても良い。

【００１８】さらに、誘電体窓は、その処理容器側の面に同心円状の段差を設けて、基板表面から誘電体窓の表面までの距離が基板の領域によって異なるようにし、生成するプラズマの密度が該基板上で均一になるように構成されたものであっても良い。この同心円状の段差は、誘電体窓の径方向に１／２波長の整数倍の直径で不連続に設けられていても良い。また、誘電体窓は、他の領域と異なった厚さを有する中央部領域や、凸部を有する領域や、同心円状の段差を有する領域を有し、これらの領域の厚さが誘電体内のマイクロ波の波長の１／４程度であっても良い。

【００１９】本発明によれば、上記したようにマイクロ波放射板の熱的強度と機械強度とを考慮した上で、マイクロ波放射板の厚さを従来の０．３ｍｍに比べて、０．５～３．０ｍｍ、好ましくは１ｍｍと厚いものを用いるとともに、厚い放射板を用いてもマイクロ波が効率よく放射できるように、マイクロ波発振器からマイクロ波透過用誘電体窓までのマイクロ波の導波路には誘電体を挿入せず、導波管内部が大気の状態になるようにし、アンテナ内の管内波長を従来よりも長くするように工夫されたアンテナ手段を用いている。このようなアンテナ手段を用いてプラズマ処理を行うことにより、マイクロ波放射板の歪によるプラズマの不安定性が解消され、安定性の高いプロセスを行うことが出来る。また、構造が簡略化され、破損が心配される高価なセラミック製の板および同軸管の内軸を支持するためのテフロン（登録商標）やセラミックスの碍子なども用いる必要がない。そのため、本発明のプラズマ処理装置は、単純な構造で短い期間で作製することが出来る。

【００２０】本発明のマイクロ波プラズマ処理方法は、上記した処理装置、すなわち、内部には誘電体板が無く、かつ、大気の状態であるアンテナ手段であって、互いに向きの異なるスロットのペアが複数組円形に一周のみ配置されているマイクロ波放射板を有するアンテナ手段を備えたマイクロ波プラズマ処理装置を用いて行われる。この際の処理容器内のガス圧は０．１Ｐａ～１０００Ｐａであり、電極に印加されるマイクロ波の周波数は２ＧＨｚ～１０ＧＨｚであることが好ましい。ガス圧が０．１Ｐａ未満であり、また、１０００Ｐａを超えると放電開始及び維持が困難となる。また、周波数が２ＧＨｚ未満であると所望のプラズマ密度が得られず、１０ＧＨｚを超えると電力増幅のための設備が大がかりになるほか、その取り扱いに難がある。

【００２１】

【発明の実施の形態】以下、本発明の実施の形態に係るマイクロ波プラズマ処理装置を、図１、２、４、５及び６を参照して説明する。図１は、本発明の実施の形態の一例として、マイクロ波を用いた半導体基板用プラズマ処理装置において、マイクロ波を導入するアンテナ手段として、アンテナ本体内部が空洞になっており、マイクロ波放射板には異なる向きの矩形スロットのペアが複数組円形（環状）に一周のみ配置されており、放射板の厚さが所定の厚さ（例えば、１．０ｍｍ）のものを用いている装置の構成を示す断面図である。図２は、マイクロ波放射板に開けられたスロットパターンの一例を示す。図４～６は、本発明の別の実施の形態に係るマイクロ波プラズマ処理装置を示す。

【００２２】図１において、１０１はプラズマ処理を行うための処理容器、１０２は同軸導波変換器およびアンテナ手段、１０３は異なる向きの矩形スロットのペア１０３ａ(ｂ)（図２に示すスロットペア１０３ａ、１０３ｂ）が複数組環状に一周のみ配置されているマイクロ波放射板、１０４はマイクロ波透過用誘電体窓、１０５はエッチングや成膜を行うために基板上方にマイクロ波電界により形成されたプラズマ、１０６はマイクロ波を発振するマグネトロン、１０７はアイソレータ、１０８はチューナー、１０９は導波管、１１０はプラズマ形成用ガスの供給手段、１１１は排気ポンプ、１１２は容器１０１内の圧力を調整する圧力調整弁、１１３はプラズマ処理をされる基板、１１４は基板を保持する電極、１１５は基板電極１１４および基板１１３に必要に応じて高周波を印加するための高周波電源、１１６は高周波のインピーダンス調整をとるための整合器である。導波管１０９からマイクロ波放射板１０３に至るまでのマイクロ波の導波路には誘電体などが挿入されておらず、また、誘電体窓１０４に至るまでのマイクロ波の導波路はすべて大気状態となっている。また、マイクロ波放射板１０３は厚さが所定の厚さ（例えば、１ｍｍ）のものを使用している。誘電体窓１０４の外周部、すなわち中央部から離れた部分には、プラズマ励起領域が直接処理容器壁の金属表面と接触しないようにリング状のスリーブ１１７が形成されている。

【００２３】以下、図１および２に示す装置を用いて行うプラズマ処理方法についての概要を説明する。本実施の形態の装置においては、ガス供給手段１１０によってプラズマ１０５を励起させるためのガスを処理容器１０１内に供給し、排気ポンプシステム１１１によって原料および反応副生成ガスを排気し、容器１０１内を減圧にし、容器１０１内のプロセス圧力を圧力調整弁１１２によって調整する。マイクロ波電源（マグネトロン）１０６で発振、増幅されたマイクロ波は、チューナー１０８を通してアンテナ手段１０２に導入され、マイクロ波放射板１０３に開けられた矩形スロット１０３ａ、１０３ｂから放射される。このとき、反射波はチューナー１０８によって容器１０１側へと戻されるが、調整しきれない反射波についてはアイソレータ１０７で吸収し、マグネトロン１０６へ戻ることを防いでいる。マイクロ波放射板１０３からスロット１０３ａ、１０３ｂを通って放射されたマイクロ波は、誘電体窓１０４を介して真空雰囲気下の容器１０１の内部へ導入され、このマイクロ波

の作る電磁界によって容器１０１内にプラズマ１０５を形成する。

【００２４】形成されたプラズマ１０５の密度が誘電体窓１０４の近傍でマイクロ波のカットオフ密度を越えると、マイクロ波の侵入長は数ミリとなってプラズマ中の数ミリの範囲において一部のエネルギーがプラズマ１０５に吸収され残りは反射される。生成されたプラズマ１０５の密度分布は、スロットパターンによっては平面で均一に調整することができるが、その時の処理容器１０１内の圧力や誘電体窓１０４の形状にも大きく依存する。このようにして生成されたプラズマ１０５は拡散によって基板１１３へ到達し、基板１１３に対して所望のプラズマ処理を施すことができる。

【００２５】次に、本発明の別の実施の形態であるプラズマ処理装置について説明する。図４に示す本発明の実施の形態の別の例であるプラズマ処理装置においては、マイクロ波の導入窓を構成する誘電体窓４０４として、同心円の領域、すなわち、円形の誘電体窓の中心から所定の等距離までの領域において大気側（マイクロ波導入側）の表面に凸部（直径：Ｄ４）を設けて、その部分の厚さを変えた誘電体窓を用いている。スロットペアのパターンは図２に示すものと同じ構成であり、また、その他の構成は図１に示すものと同じ構成であり、図４中の符号については、特に断らない限り、図１と同じ符号は同じ構成を示す。

【００２６】マイクロ波の導入窓である誘電体窓４０４は、図１に示す誘電体窓１０４と同様に以下述べる材質のものから作製され得る。厚さ５０ｍｍの石英板を用いる場合、例えば、φ＝９５ｍｍまでの範囲（Ｄ４）の領域において誘電体窓４０４の大気側を凸型にし、その凸型部分の厚さを６０ｍｍにしてある。例えば、直径（Ｄｗ）２００ｍｍのシリコン基板の直上にある誘電体窓の厚さは、基板の半径が０ｍｍから４７．５ｍｍまでの範囲（Ｄ４ｘ１／２）の領域においてその直上に位置する領域の厚さが６０ｍｍになり、その他の領域における厚さが５０ｍｍになる。

【００２７】図５に示す本発明の実施の形態の別の例であるプラズマ処理装置においては、マイクロ波の導入窓を構成する誘電体窓５０４として、同心円の領域、すなわち誘電体窓の中心から所定の等距離までの領域において図４の場合とは逆に真空側の表面に凸部（直径：Ｄ５）を設けて、その部分の厚さを変えた誘電体窓を用いている。スロットペアのパターンは図２に示すものと同じ構成であり、また、その他の構成は図１に示すものと同じ構成であり、図５中の符号については、特に断らない限り、図１と同じ符号は同じ構成を示す。

【００２８】マイクロ波の導入窓である誘電体窓５０４は、図１に示す誘電体窓１０４と同様に以下述べる材質のものから作製され得る。厚さ４４ｍｍの石英板を用いる場合、例えば、φ＝６０ｍｍまでの範囲（Ｄ５）の領域において誘電体窓５０４の真空側を凸型にし、その凸型部分の厚さを６０ｍｍにしてある。例えば、直径（Ｄｗ）２００ｍｍのシリコン基板の直上にある誘電体窓の厚さは、基板の半径が０ｍｍから３０ｍｍまでの範囲（Ｄ５ｘ１／２）の領域においてその直上に位置する領域の厚さが６０ｍｍになり、その他の領域における厚さが４４ｍｍになる。また、基板の半径が０ｍｍから３０ｍｍまでの領域（Ｄ５ｘ１／２）において、基板から誘電体板までの距離（Ｌ５２）を４０ｍｍとし、その他の領域においてはその距離（Ｌ５１）を５６ｍｍとしてある。

【００２９】図６に示す本発明の実施の形態のさらに別の例であるプラズマ処理装置においては、マイクロ波の導入窓を構成する誘電体窓６０４として、同心円の領域、すなわち誘電体窓の中心から所定の等距離までの領域においてマイクロ波導入側の表面に凸部、真空側の表面に凹部を設けるように加工し、誘電体窓自体の厚さがどの領域においても同じ厚さになるように構成した誘電体窓を用いている。スロットペアのパターンは図２に示すものと同じ構成であり、また、その他の構成は図１に示すものと同じ構成であり、図６中の符号については、特に断らない限り、図１と同じ符号は同じ構成を示す。

【００３０】マイクロ波の導入窓である誘電体窓６０４は、図１に示す誘電体窓１０４と同様に以下述べる材質のものから作製され得る。厚さ５０ｍｍの石英板を用いる場合、例えば、φ＝６０ｍｍまでの範囲（Ｄ６）の領域において誘電体窓６０４の真空側を凹型にし、基板６１３から直径（Ｄｗ）２００ｍｍの基板の直上にある誘電体窓までの距離については、基板の半径が０ｍｍから３０ｍｍまでの範囲（Ｄ６）の領域においてはその距離（Ｌ６２）を６５ｍｍとし、その他の領域においてはその距離（Ｌ６１）を６０ｍｍとしてある。上記プラズマ処理容器内の圧力は、プロセス条件により異なるが、一般に、０．１Ｐａ～１０００Ｐａ、好ましくは５Ｐａ～１０００Ｐａの範囲において所望の効果を得ることができる。誘電体窓の下面と基板の上面との距離（Ｌ１１、Ｌ４１、Ｌ５１、Ｌ５２、Ｌ６１、Ｌ６２）は、プラズマ密度、酸化速度、膜厚分布均一性等の関係により、一般に、３０ｍｍ～１２０ｍｍの範囲にすることが好ましい。

【００３１】上記したように誘電体窓の厚さを所定の範囲内で変える場合は、その厚さを誘電体内のマイクロ波の波長（λｇ）のλｇ／４程度にする事が望ましい。マイクロ波の電界強度はそこに存在する定在波の状況により交播するので、中央部が最適厚さであれば、薄い外周部ではプラズマ密度が低くなってしまう。これは、誘電体窓の厚さを単に部分的に薄くしただけではその薄い部分で電界強度が強くなるとは限らないからである。そのために、本発明におけるように、中央部の厚さを規定して、誘電体内のマイクロ波の波長のλｇ／４の段差を設

けることが効果的である。誘電体窓の厚さを変える範囲または段差をつける範囲は、同心円のリング状に配置されたものであっても、または適宜分布させて配置されたものでも良い。

【００３２】高密度のプラズマを生成するためには、投入するマイクロ波の周波数を、一般に、２ＧＨｚ～１０ＧＨｚの範囲内から適宜選択し、また、誘電体窓の直下のプラズマ密度がマイクロ波のカットオフ密度に達するようにするためには、投入電力を、誘電体窓下面の面積に対して、好ましくは１W/cm^2～５W/cm^2の範囲内から適宜選択してプロセスを行うのがよい。プロセスガスとしては、堆積膜（絶縁膜、半導体膜、金属膜等）の形成、ＣＶＤ法による薄膜（シリコン系半導体薄膜、シリコン化合物系薄膜、金属薄膜、金属化合物薄膜等）の形成、基板表面のエッチング、基板表面上の有機成分のアッシング除去、基板表面の酸化処理、基板表面の有機物のクリーニング等の各プロセスによって異なるが、公知の各種ガスを適宜選択して用いることができる。例えば、一種類以上の公知のガスをプロセス中に少なくとも合計８．５ｘ10^{-2} $Pa \cdot m^3/sec$以上導入すればよい。

【００３３】基板の支持ステージ温度は、エッチングや成膜等の各プロセスによって異なるが、一般に、－４０℃～６００℃の範囲内から適宜選択すればよい。処理対象とする基板は、特に制限されず、例えば、半導体基板に限らず、ガラス基板、プラスチック基板、ＡｌＴｉＣ基板等を使用できる。マイクロ波の導入窓を構成する誘電体としては、機械的強度が十分で、マイクロ波の透過率が十分高くなるように誘電損失が非常に小さい材料であれば特に制限されず、例えば、石英、アルミナ（サファイア）、窒化アルミニウム、窒化シリコン、フッ化炭素ポリマー等を用いることができる。

【００３４】

【実施例】以下、本発明の実施例を図面を参照して、さらに詳細に説明する。＊

＊（実施例１）図１に示す装置のアンテナ手段１０２において、図２に示す本発明のマイクロ波放射板１０３を搭載したアンテナ手段を用いた場合と、このアンテナ手段１０２の代わりに図３に示す従来のマイクロ波放射板３０３（スロットペア３０３ａ、３０３ｂ）を搭載したアンテナ手段を用いた場合とについて、生成する両者のプラズマの安定性を比較評価するため、プラズマを点火してからプラズマに点滅または大きなチューナーの変位が見られるまでの時間を計測した。

【００３５】上記評価は、マイクロ波放射板１０３、３０３をそれぞれ搭載したアンテナ手段以外は、同一の構成要素を使用した図１に示す装置を用いて行った。従来のアンテナ手段としては、アンテナの内部に厚さ４ｍｍのアルミナ誘電体の円板が挿入されており、また、図３に示すような同心円の３周のスロットペア３０３ａ、３０３ｂの切ってある直径３３６ｍｍ、厚さ０．３ｍｍのマイクロ波放射板３０３を使用した。一方、本発明のアンテナとしては、アンテナ手段１０２の内部には誘電体を挿入せず、内部を厚さ１５ｍｍの空気の層として、図２に示すような１周のスロットペア１０３ａ、１０３ｂの切ってある直径３３６ｍｍ、厚さ１ｍｍのマイクロ波放射板１０３を使用した。

【００３６】基板電極１１４には基板１１３として石英の板を置き、基板バイアスは印加しなかった。ガス供給手段１１０から処理容器１０１にＡｒガスを標準状態で０．５$Pa \cdot m^3/sec$（３００ｓｃｃｍ）導入し、排気ポンプシステム１１１と圧力調整弁１１２とによって、処理容器１０１内の圧力を２０Ｐａおよび１３３Ｐａに調整した。圧力調整の終了した後にマイクロ波電力を出力２．５ｋＷで一気に導入してプラズマを生成した。

【００３７】上記のようにして生成したプラズマが不安定になるまでに要する時間を次の表２にまとめる。

（表２）

処理容器内圧力	従来型のアンテナ手段	本発明のアンテナ手段
２０Ｐａ	１８秒	８分１０秒
１３３Ｐａ	３５秒	１０分以上

表２の結果から、本発明のアンテナ手段の場合、アンテナに起因するプラズマの安定性が大幅に向上していることがわかる。

【００３８】（実施例２）アンテナのマイクロ波パワーをプラズマへ導入する効率を比較するため、実施例１の場合と同じ従来型のアンテナ手段と本発明のアンテナ手段を用いて、プラズマ点火に要するマイクロ波パワーおよびプラズマ点火後の放電維持パワーの下限を調べた。基板電極１１４には基板１１３として石英の板を置き、基板バイアスは印加しなかった。ガス供給手段１１０から処理容器１０１にＡｒガスを標準状態で０．５$Pa \cdot m^3/sec$（３００ｓｃｃｍ）導入し、排気ポンプシステム１１１と圧力調整弁１１２とによって、処理容器１０１内の圧力を１３３Ｐａに調整した。圧力調整の終了した後にマイクロ波電力を増加していき、すなわち、ポテンショメータをみながら、マイクロ波電力を出力０．０ｋＷから徐々に導入してプラズマが点火するまで出力を増加していき、その放電開始電力を調べた。また、プラズマが点火した後も２．０ｋＷまで一旦出力を増加させ、その後、逆に出力を減少させていき放電が消

えるときの出力を調べた。
【００３９】かくして得られた放電開始電力と放電維持最小電力についての結果を次の表３にまとめる。
（表３）

	従来型のアンテナ手段	本発明のアンテナ手段
放電開始電力	４００W	４００W
放電維持最小電力	３３０W	３５０W

表３の結果から、本発明のアンテナ手段の場合、従来のアンテナ手段と比べても放電特性にはほとんど遜色がないので、マイクロ波放射板の厚みが増した（従来の放射板厚み：０．３ｍｍ、本発明の放射板厚み１．０ｍｍ）影響がほとんどないことがわかる。
【００４０】（実施例３）従来のアンテナ手段において、マイクロ波放射板のパターンは図３と同一で厚みだけを１．０ｍｍにしたものについて、実施例２の場合と同様に放電開始電力と放電維持最小電力を調べた。その結果、マイクロ波出力を２．０ｋW以上投入しても放電は起こらなかった。このことから、単に表１で示すような計算による透過電力の減少の影響によるものだけではなく、厳密にはスロットの厚み１．０ｍｍ内に誘電体が挿入されていないために、マイクロ波放射板の厚みによってマイクロ波がほとんど遮蔽されていることがわかる。
【００４１】（実施例４）図１、２、４、５、及び６に示す本発明の装置を用いてＫｒ／O_2プラズマを生成し、シリコン基板を直接酸化処理した後の処理ウェーハの酸化膜の厚さの測定について説明する。はじめに、図１および２に示す装置を用いて行うシリコン基板の酸化処理について説明する。マイクロ波の導入窓に誘電体窓１０４を設置し、シリコン基板１１３を真空処理容器１０１内にセットした後、マグネトロン１０６からマイクロ波を出力して下記の条件でプラズマを生成し、プラズマ酸化後のシリコン基板１１３の酸化膜の厚さをエリプソメータにより測定した。なお、マイクロ波放射板は実施例１～３で用いた図２に示すものを用いた。
【００４２】誘電体窓１０４として、直径３８０ｍｍ（真空容器側：３５０ｍｍ）、厚さ５０ｍｍの石英板（誘電率３．８、誘電損失＜1.0×10^{-4}＠２．４５ＧＨｚ）を設置した。マイクロ波は周波数：２．４５ＧＨｚで出力：２．５ｋW（約２．６W／cm^2）とし、ホットプレート温度を４００℃に維持し、シリコン基板１１３の上面と誘電体窓１０４の下面との間の距離（Ｌ１１）を６０ｍｍとして、基板電極１１４上にあるシリコン基板１１３には高周波バイアスを印加することなく、プラズマ処理を行った。プラズマ励起用ガスとして、Ｋｒを０．５$Pa \cdot m^3$／ｓｅｃ、O_2を1.7×10^{-2} $Pa \cdot m^3$／ｓｅｃ供給し、圧力調整弁１１２によって処理容器１０１内の圧力を１３３Ｐａに調整し、１０分間放電して、ウェーハのプラズマ酸化処理を行った。
【００４３】また、圧力調整弁１１２によって処理容器１０１内の圧力を８０Ｐａに調整したこと以外は、上記と同じ条件でプラズマ処理を行った。その結果、基板上に形成されたシリコン酸化膜の厚さの分布はほぼ同心円状となった。図７にその径方向の平均厚さを示す。図７から、８０Ｐａの場合は、基板上の外周部が中央部よりも膜厚が厚く、酸化速度が速いのに対し、１３３Ｐａの場合は、中央部の酸化速度の方が速いということがわかる。
【００４４】次に、図４に示す装置を用いて、図１および２に示す装置の場合と同様の条件で、シリコン基板４１３をプラズマ酸化処理し、酸化膜（酸化シリコン膜）の厚さをエリプソメータにより測定した。その結果、基板上に形成されたシリコン酸化膜の厚さの分布はほぼ同心円状に均一となった。図８にその径方向の平均厚さを示す。この結果を図７と比較すると、８０Ｐａの場合の酸化膜の膜厚分布から、外周部は依然中央部よりも酸化速度は速いがその差違は小さくなっており、また、分布均一性が改善されていることがわかる。さらに、全体的に酸化膜の形成速度が速くなっている。このことから、誘電体窓の形状を変更することでマイクロ波のパワーが効率的にプラズマに供給されるようになるとともに、分布均一性が向上していることがわかる。１３３Ｐａの場合も、全体的に酸化速度が速くなっており、８０Ｐａの場合と同様のことがいえる。
【００４５】さらに、図５および６に示す装置を用いて、図１および２に示す装置の場合と同様の条件で、シリコン基板５１３、６１３をプラズマ酸化処理し、酸化膜（酸化シリコン膜）の厚さをエリプソメータにより測定した。その結果、図５に示す装置の場合、基板上に形成されたシリコン酸化膜の厚さの分布はほぼ同心円状に均一となった。図９にその径方向の平均厚さを示す。この結果を図７と比較すると、８０Ｐａの場合の酸化膜の膜厚分布から、図７の場合と逆に中央部が外周部よりも酸化速度が速くなっていることがわかる。これは、シリコン基板の半径が０ｍｍから３０ｍｍまでの範囲において、誘電体窓（プラズマ生成領域）までの距離（Ｌ５２）が短いために基板に到達するプラズマの密度が他の範囲（距離：Ｌ５１）より高いためである。よって、領域ごとに真空側の誘電体窓下面から基板までの距離を近づけることでその領域での成膜速度が上昇し、また、その距離を調整することで膜厚の分布均一性を改善する事が出来る。

【００４６】また、図６に示す装置の場合、基板上に形成されたシリコン酸化膜の厚さの分布はほぼ同心円状に均一となった。図１０にその径方向の平均厚さを示す。この結果を図７と比較すると、８０Ｐａの場合の酸化膜の膜厚分布から、中央部の酸化速度が上昇する方向に改善され、また、均一性が上がっていることがわかる。一方、１３３Ｐａにおいては逆に外周部の酸化速度が上昇する方向に改善され、また、均一性が上がっている。これは、一見、上記の結果と矛盾するが、１３３Ｐａの高圧条件においては平面形状の誘電体窓１０４（図１）を用いてもプラズマが中央部に集中する傾向がある。しかし、基板中央部は誘電体窓（プラズマ生成領域）までの距離（Ｌ６２）が他の領域（距離：Ｌ６１）に比べて５ｍｍ遠いため、基板に到達するプラズマの密度が他の範囲より薄くなり、分布が改善されたと考えられる。逆に、８０Ｐａの低圧ではプラズマ密度が薄いためにプラズマは広がる傾向があるが、表面波の発生する面の一部を凹型にすることで凹型の領域でのプラズマ生成が多くなり、マイクロ波の安定結合モードが圧力条件により影響を受け難くなったためと考えられる。そのため、プラズマの広がりが抑えられ、高圧条件の場合に近い分布が得られるようになったのである。

【００４７】　上記の様に、領域ごとに誘電体窓の両面に凹凸加工を施すことで、この領域にマイクロ波のパワーを意図的に集中させ、圧力依存が少なくかつ均一性の良いプラズマの生成が可能になった。上記実施例では、図１、２、４、５および６に示すマイクロ波プラズマ処理装置を用いて、シリコン基板をプラズマ酸化処理し、酸化膜を形成したが、同じプラズマ処理装置を用いて、半導体ＬＳＩ作製における被処理物である基板に対して、成膜、エッチング、膜組成の改善・改質、アッシング等の工程を、公知の薄膜形成ガス、エッチャントガス、アッシングガス等を用いて行うことができた。

【００４８】

【発明の効果】以上詳細に説明したように、本発明によれば、マイクロ波放射板の熱的強度と機械強度とを考慮した上で、マイクロ波放射板として従来のものより厚いものを用いるとともに、この厚い放射板を用いてもマイクロ波が効率よく放射できるように、マイクロ波発振器からマイクロ波透過用誘電体窓までのマイクロ波の導波路には誘電体を挿入せず、かつ、導波路内を大気状態として、アンテナ内の管内波長を従来よりも長くするように工夫されたアンテナ手段を用いたプラズマ処理装置が提供され、この装置を用いてプラズマ処理を行うことにより、マイクロ波放射板の歪によるプラズマの不安定性が解消され、安定性の高いプロセスを行うことが出来る。また、本発明のプラズマ処理装置によれば、構造が簡略化され、破損が心配される高価なセラミック製の板および同軸管の内軸を支持するテフロンやセラミックスの碍子なども用いる必要はなく、この処理装置を単純な構造で、短い期間で作製することが出来る。

【図面の簡単な説明】

【図１】　本発明の実施の形態に係るマイクロ波プラズマ処理装置の一構成例を示す模式的な断面図。

【図２】　本発明に係るマイクロ波プラズマ処理装置においてアンテナ手段に用いるマイクロ波放射板のアンテナパターンの一例を模式的に示す平面図。

【図３】　本発明に係るマイクロ波プラズマ処理装置において従来型のアンテナ手段に用いるマイクロ波放射板のアンテナパターンの一例を模式的に示す平面図。

【図４】　本発明の別の実施の形態に係るマイクロ波プラズマ処理装置の構成を示す模式的な断面図。

【図５】　本発明の別の実施の形態に係るマイクロ波プラズマ処理装置の構成を示す模式的な断面図。

【図６】　本発明のさらに別の実施の形態に係るマイクロ波プラズマ処理装置の構成を示す模式的な断面図。

【図７】　図１に示す装置を用いて形成されたシリコン酸化膜について、その径方向の平均厚さを示すグラフ。

【図８】　図４に示す装置を用いて形成されたシリコン酸化膜について、その径方向の平均厚さを示すグラフ。

【図９】　図５に示す装置を用いて形成されたシリコン酸化膜について、その径方向の平均厚さを示すグラフ。

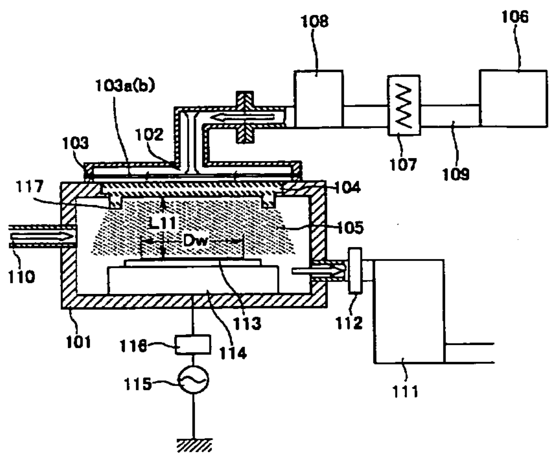
【図１０】　図６に示す装置を用いて形成されたシリコン酸化膜について、その径方向の平均厚さを示すグラフ。

【符号の説明】

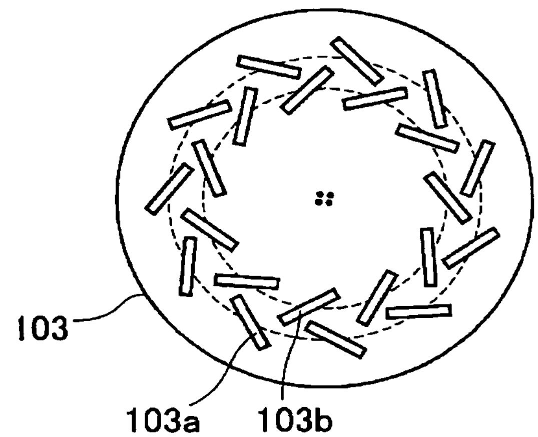
１０１　プラズマ処理容器本体　１０２　同軸導波変換器およびアンテナ
１０３　マイクロ波放射板　１０４　真空シール用誘電体窓
１０５　プラズマ　１０６　マグネトロン
１０７　アイソレータ　１０８　チューナー
１０９　導波管　１１０　ガス供給手段
１１１　排気ポンプシステム　１１２　圧力調整弁
１１３　基板　１０３ａ、１０３ｂ　スロット
１１４　基板電極　１１５　基板電極用高周波電源
１１６　基板電極用整合器　１１７　スリーブ
３０３　マイクロ波放射板　３０３ａ、３０３ｂ　スロット
４０４　誘電体板窓　４１３　基板
Ｌ４１　誘電体板窓－基板間距離　Ｄｗ　基板領域
Ｄ４　誘電体板窓厚さ変更領域　５０４　誘電体

板窓
５１３　基板　Ｌ５１　誘電体
板窓－基板間距離
Ｌ５２　誘電体板窓－基板間距離（厚さ変更部）
Ｄ５　誘電体板窓厚さ変更領域　６０４　誘電体＊
＊板窓
６１３　基板　Ｌ６１　誘電体
板窓－基板間距離
Ｌ６２　誘電体板窓－基板間距離（形状変更部）
Ｄ６　誘電体窓厚さ変更領域

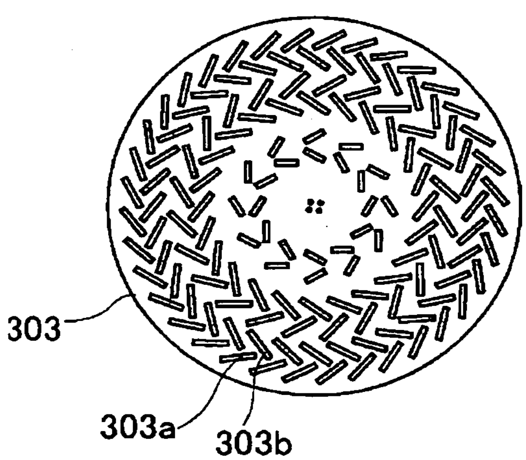
【図１】



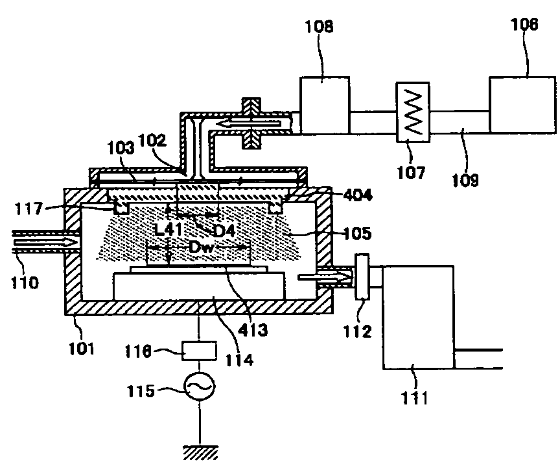
【図２】



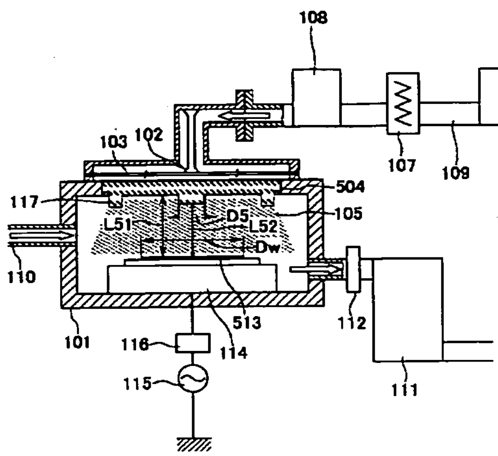
【図３】



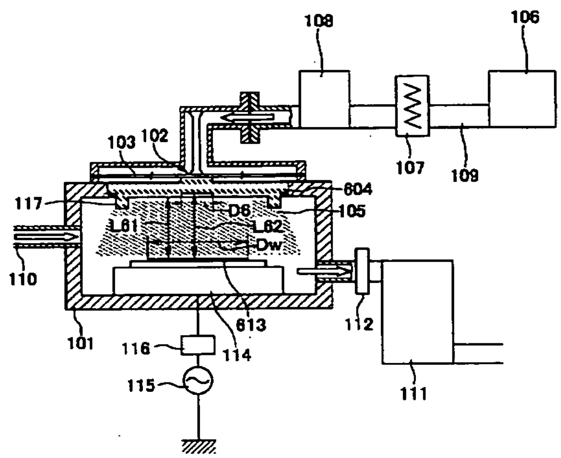
【図４】



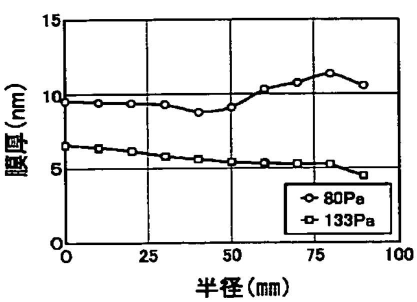
【図５】



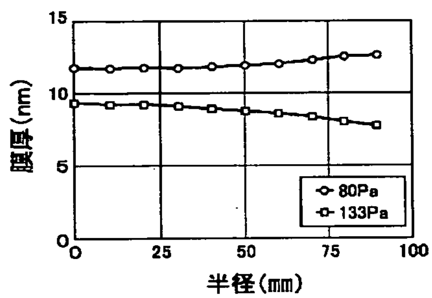
【図６】



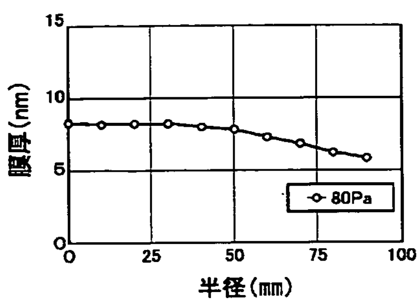
【図７】



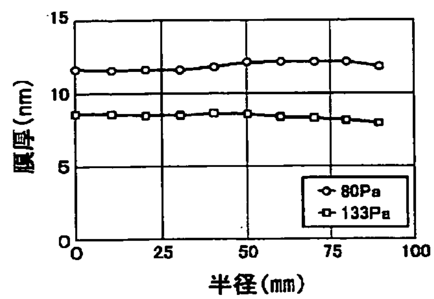
【図８】



【図９】



【図１０】



フロントページの続き

Ｆターム(参考)	4K030	FA01 JA01 JA09 JA16 JA18 KA15 LA15
	5F045	AA09 AB32 AC11 AC16 DP04 EH02 EH03